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# Control Alters Risk-Taking: The Motivating Impact of Action-Effectiveness in Different Risk Contexts

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Risk-taking is traditionally explained through outcome-value expectancy models. Recently, however, it has been demonstrated that immediate versus delayed feedback increases risk-taking independently of expected value. The current work takes a novel approach to investigate behavioral motivation in different risk-taking contexts, building on recent progress in identifying the reinforcing impact of action-effectiveness. Participants performed 1 of 2 different versions of the Balloon Analogue Risk task (BART) in which an action increases (Experiment 1 and 2) or decreases (Experiment 3) the risk of losing real money. Importantly, action-effectiveness was subtly manipulated. In 3 experiments, we found that action-effectiveness reinforces action tendency in both risk-taking contexts. In addition, the reinforcing effect was independent of participants' explicit knowledge regarding the action-effectiveness manipulation and their deliberate expectancy-based risk strategy. Overall, the findings strongly suggest that action-effectiveness motivates action and not risk-taking per *SE* Accordingly, the findings shed light on the BART suggesting that in this task, higher scores could be due to higher motivation for action and not necessarily to more risk-taking.

*Keywords:* control, motivation, risk-taking behavior, sense of agency, action-selection

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Risky behavioral decisions may have a dramatic impact on one's life. While they have the potential to maximize reward for the actor (e.g., investing in a profitable startup company in its early-stage), risky actions often result in both personal loss and social harm (e.g., drug use, unsafe driving, and unprotected sex; Zuckerman & Kuhlman, 2000). For decades, both individual (e.g., Atkinson, 1957; Zuckerman & Kuhlman, 2000) and situational (e.g., Gardner & Steinberg, 2005; Tversky & Kahneman, 1981) determinants for risk-taking behavior were intensively investigated and mostly explained through mechanisms associated with outcome-value expectancy.

More specifically, outcome expectancy-based models have traditionally been used to explain behavioral decisions under risk, commonly implemented by a variability in the outcome distribution (e.g., Lejuez et al., 2002; see also, Libby & Fishburn, 1977). Such models suggest that one's decision to behave in a certain way depends on the expected outcome value of action alternatives (for review see, Williams et al., 2005). From a similar perspective, personality factors such as impulsivity (Lejuez et al., 2002; Stanford et al., 2009) and motivational orientation (Atkinson, 1957; Lopes, 1987) have been suggested to increase risk-taking behavior by modulating such value expectancy of positive outcomes associated with the risky act (e.g., Doran et al., 2007; see also, Schiebener & Brand, 2015;). Thus, risky behavioral decisions have been explained through a deliberate process through which expected positive outcome values outweigh possible negative outcome values (Fromme et al., 1997).

Recently, however, it was demonstrated that risk-taking is also increased by factors unrelated to expected outcome value directly. Damen (2019) found that risk-taking in the Balloon Analog Risk task (BART; Lejuez et al., 2002) was increased when participants received immediate, rather than delayed feedback. In the original BART, participants accumulate money by inflating a virtual balloon. At any point, participants can secure their monetary gain by saving the accumulated money or press a key to pump the balloon for another step and risk an explosion and the loss of the accumulated money on that trial. Damen (2019) found that immediate feedback increased explicitly reported experiences of agency as well as the two key indicators of risk-taking (Lejuez et al., 2002) in the BART: the adjusted average number of pumps and the number of popped balloons. However, while Damen suggested that experienced agency influenced participants' perceived ability to control risks which in turn increased their pumping responses, recent developments in cognitive psychology and neuroscience suggest that such action-effectiveness—a perceptual effect that is contingent and temporally contiguous on one's action—may promote action-tendency directly, that is independent of explicit judgments and

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Experiment 2 in the current study was pre-registered at Open Science Framework: https://osf.io/vbzd4.
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deliberate outcome expectancy-based considerations (Eitam et al., 2013; Hemed et al., 2020; Karsh et al., 2016; Karsh et al., 2020; Karsh & Eitam, 2015a; Penton et al., 2018; Tanaka et al., 2021).

Accordingly, we claim here that direct effects on actions indicative of risk-taking (i.e., increased pumping) can be understood as the reinforcing effect of action-effectiveness. Crucially to the context of risk-taking, this reinforcing effect of action's effectiveness should not necessarily promote risk-taking, but action tendencies in general, which may increase or decrease risk-taking depending on the context.

In the present article, we demonstrate in three experiments using an adapted BART paradigm that immediate (action-effectiveness feedback) versus delayed action-effect can increase action tendencies. Moreover, we show that while increased action tendencies are often associated with increased risk-taking, action-effectiveness feedback can also lead to less risk-taking in a setting in which increased action tendencies decrease risk.

## The Motivating Impact of Action-Effectiveness

Having an own-action effect has been suggested for decades to motivate behavior in and of itself (e.g., Higgins, 2012; Skinner, 1953; Stephens, 1934; White, 1959). For instance, Higgins (2012) suggested that control-effectiveness (e.g., "managing what happens" or "having an effect" on the environment; see also., White, 1959) has its distinct motivating impact on behavior, which is independent of value-effectiveness (e.g., "ending with the desired outcome). Such reinforcement from the mere effectiveness of one's action was suggested to be critical for acquiring an own-action-effect association (Elsner & Hommel, 2004; Karsh et al., 2016), enabling an infant to become a goal-directed agent that acts purposefully on her environment (Hauf et al., 2004). These ideas gained some support by neuroscientific findings documenting the sensitivity of both the brain's reward (Behne et al., 2008; see also, Rao et al., 2008; Tricomi et al., 2004;) and motor systems (Hughes & Waszak, 2011) to the mere effectiveness of one's action.

Recently, its facilitating impact on both the speed and frequency of action selection was empirically demonstrated (Eitam et al., 2013; Karsh et al., 2016). A Control-based response selection (CBRS) framework was recently proposed (Karsh & Eitam, 2015b) and empirically supported (Eitam et al., 2013; Karsh Eitam, 2015a; 2016; 2019; Penton et al., 2018), linking the process through which the motor-system determines its effectiveness (e.g., differentiating own from externally caused effect) to motivated action-selection.

More specifically, previous work on how the effectiveness of one's action is determined by the mind suggests that one route through which an effect can promote action-selection is by its registration as an own-action effect, adhering to parameters that are important for the mechanism responsible for motor-based computation of agency (Karsh et al., 2016; e.g., the comparator model; Blakemore et al., 1999; ). According to the comparator model, the determination of an action's effectiveness depends on minimal discrepancy between a forward sensory prediction model (that is generated by an efference copy of the motor command) and the representation of the actual sensory feedback. Important for the current study, such detection (among others) is suggested to be sensitive to the temporal discrepancy between an action and action-effect (Blakemore et al., 1999; Haggard et al., 2002; Karsh et al., 2016).

Accordingly, different implicit measures of agency such as the temporal binding effect (Haggard et al., 2002), the sensory attenuation effect (Blakemore et al., 1999), and most relevant to the current work, the reinforcing impact of action-effectiveness; were all found to be disrupted by a subtle lag ($>\sim$300ms) between action and action-effect.[1]

For instance, in a task in which participants were asked to respond randomly on each trial by pressing one of four relevant keys on a keyboard whenever a response-cue appeared on their screen, their responses were biased toward the key that produced an immediate effect (a brief white flash) compared to a 450ms lagged effect key (Exp. 1c; Karsh et al., 2016). Such response bias, favoring the immediate effect key, actually damaged their task performance (in this case to respond randomly).

## The Current Study

Based on the above, we aimed to examine the reinforcing impact of action-effectiveness as determined within the motor system namely, a perceptual effect that is contingent and temporally contiguous on one's action. Different from previous studies, such reinforcement was examined in different experimental contexts in which performing an action increases (Experiments 1 and 2) and decreases (Experiment 3) the actual risk of losing real money. Moreover, we explored whether the reinforcing impact of action-effectiveness holds regardless of participants' explicit knowledge regarding the effectiveness manipulation, their explicit perception of being influenced by it, and their deliberate expectancy-based risk strategy.

In Experiments 1 and 2, we used a modified version of the Balloon Analog Risk task (BART; Lejuez et al., 2002). Crucially, the temporal-contiguity of the pump effect (the size and the pump sound of the balloon) was subtly manipulated. This manipulation was not intended to be subliminal; however, it has previously been demonstrated to yield minimal explicit knowledge when it was not intentionally attended to (i.e., when it was irrelevant to task performance; Karsh et al., 2016).

In Experiment 1, we tested the hypothesis that mere action-effectiveness directly increases action tendency resulting in riskier behavior. In Experiment 2, we aimed to replicate the findings of Experiment 1 and to further explore whether the documented motivating effect depends on participants' explicit recognition of the lag manipulation, their perception of whether the manipulation affected their performance, and their deliberate expectancy-based risk strategy.

To distinguish between increased risk-taking and increased action tendency, we moved beyond the current version of the task in Experiment 3 and developed an inverse BART (iBART) in which acting *decreases* the risk of losing. Hence, considering the results of Experiments 1 and 2, Experiment 3 can provide a decisive answer to the question of whether action-effectiveness makes people more prone to take a risk, or reinforces action as suggested by the CBRS framework. Also, in Experiment 3 we aimed at replicating the findings of Experiment 2 regarding the contribution of explicit knowledge of the temporal contiguity manipulation and deliberate expectancy-based risk-taking strategy to action tendency.

[1] Note, that explicit judgment of agency (in contrast to implicit measures of agency) may still be positive after longer action-effect delay (e.g., 1100ms; Farrer et al., 2008). Such difference between implicit and explicit measures implies a different degree of involvement of efference copy-based sensorimotor predictions and high-level cognitive expectations in these measures (for a recent discussion see Wen, 2019).

Finally, in all three Experiments, we tested whether individuals with different impulsivity trait levels demonstrate differential sensitivity to action-effectiveness in their action tendency.

## Experiment 1: Action-Effectiveness Feedback Increases Risk-Taking

### Method

#### *Participants*

Fifty-four undergraduate students [33 females, Age ($M$ = 25.18, $SD$ = 2.39)] from Tel-Hai Academic College, Israel were recruited to participate in a study in exchange for course credit (only relevant to undergraduate psychology students) and monetary compensation according to their performance in the experiment. G-power software (Faul et al., 2007) was used to estimate the required sample size needed to achieve .95 power to detect a medium effect size (dz = .5) for a two-tailed comparison between two paired means. Written informed consent was obtained from all participants. The study was approved by the institutional review board of Tel-Hai Academic College.

#### *Stimuli and Procedure*

Participants were invited to the lab and sat in an individual cubicle under dim lighting in front of a computer monitor and were introduced to a modified version of the Balloon Analogue Risk task (BART; Lejuez et al., 2002). First, participants read the following instructions in Hebrew:

> *In this game, you need to earn as much money as you can in a balloon inflation task. Each pump entitles an amount of real money, but if you pump the balloon too much, it will explode, and the money earned will be lost. Each balloon can be inflated to a different size, but you will not be able to know in advance the balloon's maximum size. Press the SPACE key to inflate the balloon. Press the ENTER key to save the money you have accumulated in the bank and continue to the next balloon. At the end of the game, you will receive the amount of money you have accumulated in the bank. Note, the number of balloons in the game was pre-set. The experiment's total duration is 30 minutes. Try to earn the maximum amount of money for every new balloon and save the money in the bank before the balloon explodes. Press the SPACE key to start inflating the first balloon.*

Note that although the duration of the experimental task was ∼10 minutes, we intentionally presented it as a 30-minute experiment to minimize any urgency by the participants to finish the experiment. Also, we informed participants that the number of balloons to be inflated is fixed to minimize any deliberate strategy to inflate as many balloons as possible (which may result in a minimal number of pumps for each balloon).

Each trial began with a presentation of a red balloon on the left side of the monitor and participants were to inflate the balloon by pressing the 'SPACE' key on a standard keyboard (Figure 1). Each inflation was awarded by .05 NIS (∼.014$) and at any point, participants could stop pumping the balloon and press the 'ENTER' key to permanently secure their earnings. If a balloon was pumped and reached its explosion point, a "pop" sound effect was generated, all the money collected in the specific trial was lost, and a new uninflated balloon appeared on the screen.

Participants were not informed about the total number of trials (balloons) in the task and the balloons' explosion points. Importantly, each pump response affected the balloon—an increase in the size which was accompanied by a balloon inflation sound.

Crucially, to investigate the motivating impact of action-effectiveness on pumping responses, we manipulated the temporal contiguity between the pump response and both the visual and auditory effects (the pump effect) by inserting a subtle lag in half of the trials. Specifically, in the Immediate condition, the pump effect appeared immediately after the pump response – 'pure' effectiveness feedback; while in the Lag condition, the pump effect appeared 450ms after the pump response (no effectiveness feedback). A predefined list of thirty possible sizes was identical for the two Temporal contiguity conditions. On each trial, the computer selected one balloon from that list in a random order without replacement ($M_{\text{maximum pumps}}$ = 23.5, $SD_{\text{maximum pumps}}$ = 11.38; Min = 2, Max = 45). Participants performed 30 trials in each condition (overall 60 trials) which were presented in random order.

At the end of the task, participants completed an electronic version of the Barratt Impulsiveness Scale (BIS-11; Patton et al., 1995). The BIS-11 includes 30 items designed to assess impulsiveness. Each item includes a statement and participants indicate the degree the statement characterizes them from 1 (never) to 4 (always). The scale includes statements addressing Motor Impulsiveness (acting without thinking), Nonplanning Impulsiveness (a lack of forethought), and Attentional Impulsiveness (an inability to focus attention or concentrate; Barratt, 1985). Previous studies demonstrated a high internal consistency of items in BIS-11 and it was found to be correlated with several types of risky behaviors (for a review see: Stanford et al., 2009). Finally, participants completed a demographic questionnaire and were compensated with the amount of money they had secured in the task.

Based on the CBRS framework, we predicted that pump responses will be higher in the Immediate compared to the Lag condition. In addition, we explored whether participants with high (compared to low) impulsivity trait levels, will be more sensitive to action-effectiveness, demonstrating a larger difference in pumping responses between the Immediate and the Lag conditions[2].

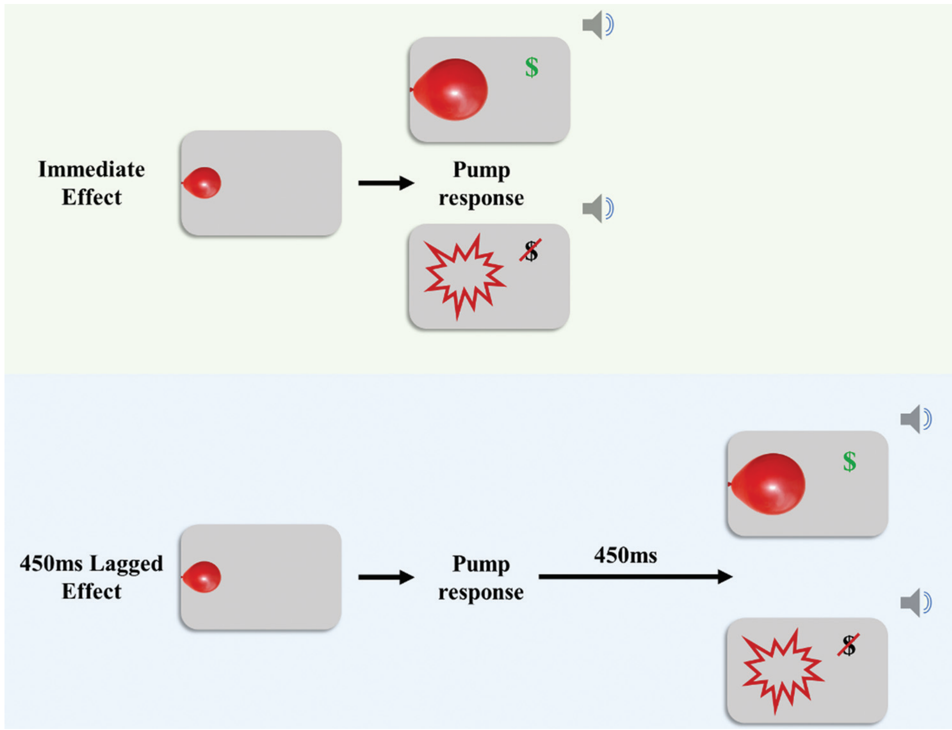
### Results

As in previous studies using the BART (e.g., Lejuez et al., 2002), the adjusted mean number of pumps was the main indicator for risk-taking actions in the current study. The adjusted mean number of pumps was created by averaging the number of pumps for each participant in each condition, excluding trials in which the balloon was exploded (Lejuez et al., 2002). Additional analyses were conducted on the number of explosions. We used two-tailed t-tests for all comparisons. In addition, to quantify the degree the data supports one of the hypotheses (the alternative or the null), we further conducted nondirectional Bayesian t-tests

[2] To minimize the risk of insuffitient power, the interaction between Impulsivity and action effectiveness was tested on the pooled data from all three experiments. The coresponding analyses of the indivual experiments are reported in the online supplemental material.

**Figure 1**

*A Schematic Illustration of All Types of Trials in the Current Version of the Balloon Analogue Risk Task*




*Note.* On each trial, a pump response affected the balloon by increasing its size, which was accompanied by an inflation sound and a monetary gain. If the balloon reached its explosion point, a 'pop' sound was displayed, and participants lost the accumulated money on that trial. See the online article for the color version of this figure.



using JASP software (JASP Team, 2019) with the default Cauchy prior (width = .707) and report the Bayes factor (BF).

As predicted, adjusted mean number of pumps was higher in the Immediate ($M$ = 15.54, $SD$ = 3.73) compared to the Lag ($M$ = 13.99, $SD$ = 3.88) condition [$t_{53}$=5.03, $p < .001$, $CI_{95}$ (.93, 2.16), $d$ = .68, $BF_{10}$ = 3039 (very strong evidence); Figure 2; see also Figure S1 in online supplemental material]. Consistently, the number of explosions was higher in the Immediate ($M$ = 9.68, $SD$ = 3.2) compared to the Lag ($M$ = 8.53, $SD$ = 3) condition [$t_{53}$=3.89, $p < .001$, $CI_{95}$ (.55, 1.73), $d$ = .52, $BF_{10}$ = 88.25 (very strong evidence)], reflecting the high correlation between adjusted mean number of pumps and number of explosions ($r$ = .84, $p < .001$).

To sum up the above, Experiment 1 demonstrates strong evidence for the motivating impact 'pure' effectiveness-feedback has on action-selection, which in the current context results in riskier behavior. The findings are consistent with the CBRS framework by demonstrating the reinforcing impact of action-effectiveness and extend previous findings by demonstrating the effect in an ecologically valid experimental environment involving risk. However, the mechanism behind this effect is not clear; specifically, whether participants' explicit recognition of the manipulation (e.g., noticing the different lags) modulated their deliberate behavioral intentions or that action-effectiveness motivated action-selection directly (e.g., regardless of explicit considerations and their deliberate expectancy-based risk strategy). Thus, the major goal of Experiment 2 (this experiment was preregistered: https://osf.io/vbzd4)[3], was to replicate the findings of Experiment 1. In addition, we further explored whether participants' explicit knowledge regarding the manipulation, their perception of whether the manipulation affected their performance, and their deliberate expectancy-based risk strategy explain this reinforcing effect.

## Experiment 2: Action-Effectiveness Feedback Increases Risk-Taking Independent of Deliberate Expectancy-Based Risk Strategy: A Replication and Extension

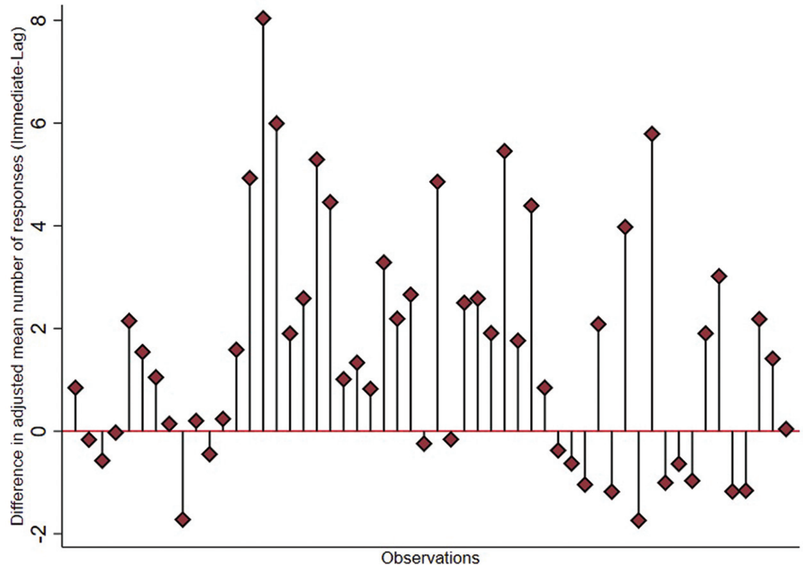
### Method

#### *Participants*

Fifty undergraduate students [30 females, Age ($M$ = 25.28, $SD$ = 2.14)] from Tel-Hai Academic College, who did not participate in Experiment 1 were recruited to participate in a study in exchange for course credit (relevant to undergraduate Psychology students) and monetary compensation according to their task performance. Written informed consent was obtained from all participants. Similar sample

[3] The most critical prediction that was specified in the pre-registration was that the number of pumps will be higher in the Immediate compared to the Lag condition. Also specified in the pre-registration is that the high (compared to low) impulsivity group will show a stronger bias toward immediate (compared to lagged) effect when pumping the balloon. Predictions regarding explicit reports of awareness and deliberate expectancy-based risk strategy were not addressed in the pre-registration and hence, these analyses were further replicated in Experiment 3.

**Figure 2**
*Experiment 1: Difference in the Adjusted Mean Number of Pumps for Each Observation*




*Note.* A value above zero on the y-axis indicates a bias toward the immediate effect over the lagged effect balloons and vice-versa. See the online article for the color version of this figure.



size to Experiment 1 was used. Crucially, regardless of significance, in Experiment 2 we used a conclusive Bayes Factor (BF $>$ 3 or BF $<$ .3, using the same parameters as in Experiment 1) for the critical comparison (the difference in the adjusted mean number of pumps between the Immediate and the 450ms Lag conditions) as a stopping-rule (only one step was required to yield conclusive results for the critical comparison).

### *Stimuli and Procedure*

The experimental task and the experimental procedure were identical to Experiment 1. Also, at the end of the experimental task we probed participants' explicit awareness of the manipulation, their perception of whether the manipulation affected their task performance, and the degree they deliberately attempted to apply a risky strategy in the task in the following way:

**Explicit Awareness Index.** To minimize dishonesty, participants were presented with five statements of possible events that may have happened during the task and were asked to indicate whether they had noticed one or more of these events (e.g., "one of the balloons was in a different color"; "I did not notice any of the described events"). Importantly, only one statement indicated an event that happened, which was the temporal contiguity manipulation (e.g., "on some trials, the balloon inflation happened immediately after my response and on some other trials it happened after about a half a second"). Participants were assigned to the Aware group if they correctly and exclusively selected the correct statement. The rest were assigned to the Unaware group.

**Perceived Influence Index.** Participants were presented with the same five statements of possible events that may have happened during the task and were asked to select one or more of the five statements if the event(s) was both noticed during the task and they believe it (or they) affected their performance. Participants were assigned to the Perceived influence group if they correctly and exclusively marked the correct statement. The rest were assigned to the Perceived no-influence group.

**Deliberate Outcome Expectancy-Based Risk Strategy.** Participants read the following:

> *Different participants use different strategies in this task. Some use a daring strategy by inflating each balloon many times to maximize their gain; and some use a cautious strategy, inflating each balloon a small number of times to minimize explosions. Please indicate on the following scale the option that best describes your strategy during the task.*

Participants were then asked to rank their strategy from 1 (*very cautious;* a small number of pumps) to 7 (*very daring;* many pumps).

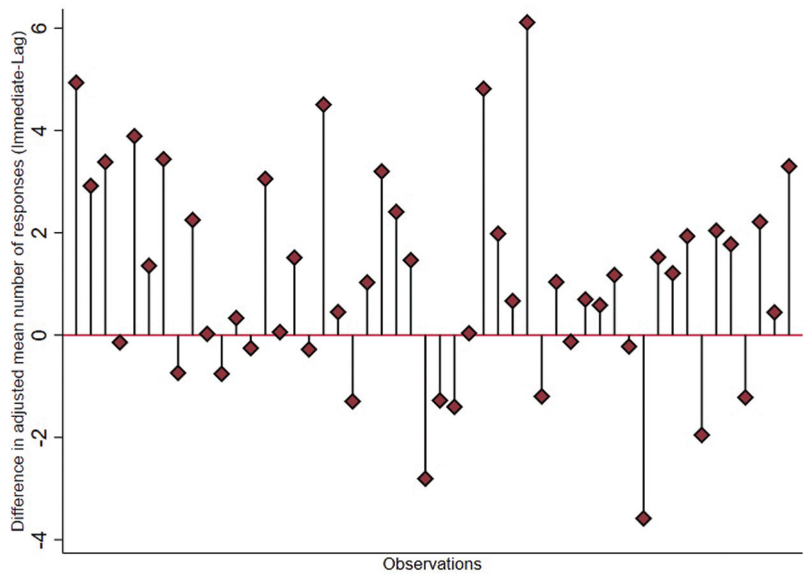
According to the CBRS framework, our working hypothesis was that action-effectiveness will facilitate behavioral risks even when participants will not be explicitly aware of the lag manipulation and regardless of their perception of being influenced by it. However, given a possible dominance of high-level deliberate processes on risk-taking actions (i.e., a prominent preplanned behavioral risk strategy that may mask some of the direct impacts of action-effectiveness), we explored the unique contribution of both action-effectiveness and explicit expectancy-based risk strategy to risk-taking behavior.

## Results

Replicating the findings of Experiment 1, the adjusted mean number of pumps was higher in the Immediate ($M$ = 14.74, $SD$ = 3.89) compared to the Lag ($M$ = 13.65, $SD$ = 4.03) condition [$t_{49}$ = 3.78, $p < .001$, $CI_{95}$ (.51, 1.66), $d$ = .53, $BF_{10}$=61.89 (very strong evidence); Figure 3; see also, Figure S2 in online supplemental material]. As in Experiment 1, the adjusted mean number of pumps was highly correlated with the number of explosions ($r$ = .82, $p < .001$). Consistently, the number of explosions was higher in the Immediate ($M$ = 9.46, $SD$ = 3.48) compared to the Lag ($M$ = 7.96 $SD$ = 3.27) condition [$t_{49}$

**Figure 3**

Experiment 2: *Difference in the Adjusted Mean Number of Pumps for Each Observation. A Value Above Zero on the Y-Axis Indicates a Higher Bias Toward the Immediate Effect Over the Lagged Effect Balloons and Vice-Versa*




*Note*. See the online article for the color version of this figure.

= 4.54, $p < .001$, $CI_{95}$ (.83, 2.16), $d = .64$, $BF_{10} = 590$ (very strong evidence)]. Thus, the findings fully replicate those observed in Experiment 1, confirming that pure effectiveness feedback reinforces action tendency which results in a riskier behavior in the current experimental context.

### *Explicit Awareness, Perceived Influence, and Deliberate Outcome Expectancy-Based Risk Strategy*

According to our Explicit Awareness index, twenty-seven participants (54%) recognized the temporal contiguity manipulation. A two-way mixed model ANOVA with Explicit awareness as a between-subjects factor and Temporal contiguity as a within-subject factor on the adjusted mean number of pumps yielded the expected main effect of Temporal contiguity [$F(1, 48) = 13.67$, $\eta2_{partial} = .22$, $p < .001$, $BF_{10} = 57$ (very strong evidence)]. No main effect of Explicit awareness [$F(1, 48) = .07$, $\eta2_{partial} = .001$, $p = .79$, $BF_{10} = .53$ (inconclusive)] and no interaction between Explicit awareness and Temporal contiguity [$F(1, 48) = .38$, $\eta2_{partial} = .007$, $p = .53$, $BF_{10} = .33$ (inconclusive)] was observed.

Next, we tested whether participants' perception of being influenced by the manipulation affected their adjusted mean number of pumps [22 participants (44%) believed the manipulation affected their performance]. A two-way mixed model ANOVA with Perceived influence as a between-subjects factor and Temporal contiguity as a within-subject factor on the adjusted mean number of pumps yielded the expected main effect of Temporal contiguity [$F(1, 48) = 13.75$, $\eta2_{partial} = .22$, $p < .001$, $BF_{10} = 57$ (very strong evidence)]. No main effect of Perceived influence [$F(1, 48) = .18$, $\eta2_{partial} = .003$, $p = .66$, $BF_{10} = .52$ (inconclusive)] and no interaction between Perceived influence and Temporal contiguity [$F(1, 48)$=.01, $\eta2_{partial} = .0001$; $p = .93$, $BF_{10} = .28$ (conclusive support for the null)] was observed.

Finally, to test whether the Deliberate outcome expectancy-based risk strategy affected their actual risk-taking actions, we regressed both Temporal contiguity and Deliberate expectancy-based risk strategy score to predict their adjusted mean number of pumps in the task ($R^2 = .33$, Root $MSE = 3.27$; adjusted for 50 clusters of participants). As expected, Temporal contiguity significantly predicted the adjusted mean number of pumps [Coef. = −1.08, $p < .001$, $\beta = -.13$, $CI_{95}$ (−1.67, −.5)]. In addition, Deliberate expectancy-based risk strategy level predicted adjusted mean number of pumps [Coef. = 1.91, $p < .001$, $\beta = .56$, $CI_{95}$ (1.29, 2.53)]; meaning that the riskier the strategy participants deliberately took, the higher their adjusted mean number of pumps was. Next, we added the interaction term to the model which was found insignificant [Coef. = .25, $p = .25$, $\beta = .15$, $CI_{95}$ (−.19, .71)].

To sum up, Experiment 2 provides a conclusive replication for the reinforcing impact action-effectiveness has on action tendency in a context where action increases risk. The findings are consistent with the CBRS framework by demonstrating that such reinforcing effect operates directly; namely, independent of participants' explicit awareness of the effectiveness manipulation and their deliberate expectancy-based risk strategy. Experiment 3 was conducted to replicate these findings in a very different risk context; namely, when acting reduces the risk of losing.

## Experiment 3: Action-Effectiveness Feedback Decreases Risk-Taking in the Inverse BART

### Method

#### *Participants*

Thirty-eight undergraduate students [29 females, Age ($M$ = 22.92, $SD$ = 4.65)] from Tel-Hai Academic College were recruited to participate in a study in exchange for course credit (only relevant to undergraduate psychology students) and monetary compensation according to their performance in the experiment. The sample size was predetermined to yield 85% power for detecting a medium effect size (dz = .5) in a two-tailed comparison between two paired means. Regardless of significance and like in the previous experiment, we report the Bayes factor (BF) to quantify the degree to which the data support one of the hypotheses, the alternative or the null. Written informed consent was obtained from all participants.

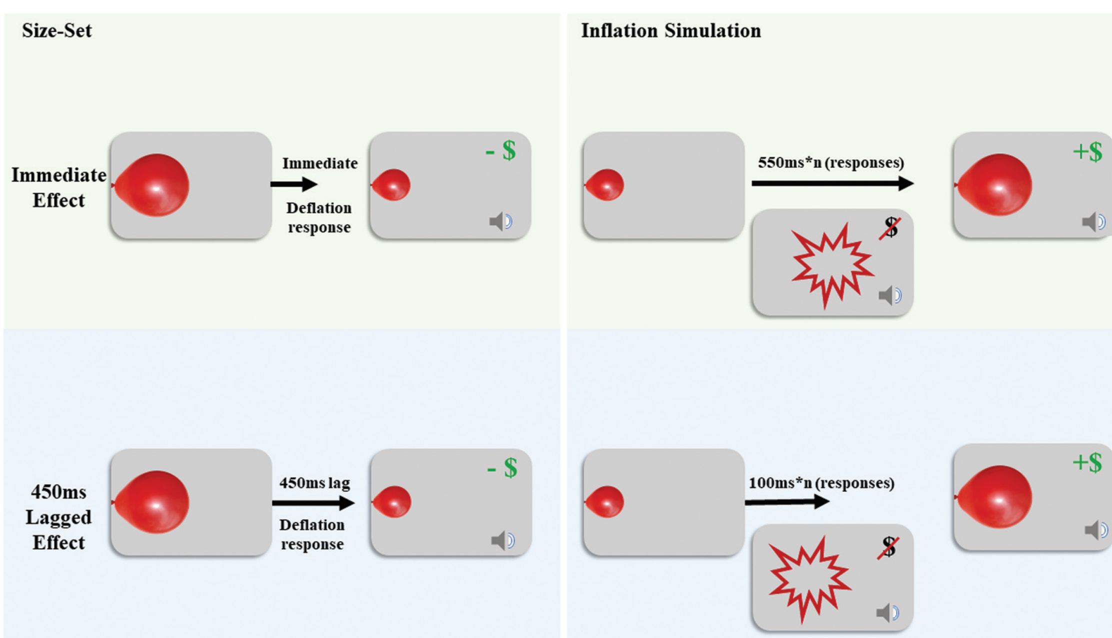
### *Stimuli and Procedure*

Participants were invited to the lab and were introduced to a novel computerized task we developed for the current study namely, an inverse version of the Balloon analog risk task (iBART; Figure 4). Unlike the original BART (Lejuez et al., 2002), in the iBART, a response deflates an animated balloon and thus, reduces the risk of its explosion. Participants read the following instructions in Hebrew:

> In this game, you need to earn as much money as you can in a balloon inflation task. At the beginning of each trial, you will need to set the extent to which the balloon will be inflated. The larger the size of the balloon will eventually be, the more money you will gain. However, if the balloon will be inflated too much, it will explode, and the money earned will be lost.
>
> *At first, you need to deflate a balloon by pressing the 'SPACE' key—this is how you will set the size you want the balloon to be. You will need to press the 'ENTER' key when you deflate the balloon to the size you want.*
>
> *If you only deflate the balloon slightly, it may overreach its maximal size and explode. In this case, you will lose the monetary gain for the specific balloon. If you deflate the balloon enough, the balloon could be inflated to the size you set, and you will receive the amount of payment from the experimenter at the end of the experiment.*
>
> *Note, you will not be able to know what the maximal size of a balloon is. Each deflation response at the first part of the trial reduces its monetary value but also decreases the chance of its explosion during the second part of the trial. On the other hand, conducting few deflation responses increases the chance of explosion, but if you win, the monetary gain will be higher.*
>
> *Try to earn as much money as you can. Press the SPACE key to start a practice session."*

Each trial includes two parts, a size-set part, and an inflation simulation part. The first size-set part of each trial begins with a presentation of a full-sized red balloon on the left side of the monitor. Participants are to set the size they want the balloon to reach in the second simulation part by deflating the balloon using the 'SPACE' key on a standard keyboard. Each deflation response decreases the size of the balloon and reduces its monetary value by .05 NIS (∼.014$). At any point, participants can stop deflating the balloon and press the 'ENTER' key to proceed to the second simulation part of the trial. In the second simulation part, a minimal-sized red balloon appears at the left side of the monitor and is inflated automatically until it reaches the size that was preset by the participant or explodes if it reaches its explosion point. If a balloon reaches the participant's predetermined size without exploding, its monetary

**Figure 4**
*A Schematic Illustration of All Types of Trials in the Inverse Balloon Analogue Risk Task*




*Note.* On the first size-set part of the trial, a deflation response affects the balloon by decreasing its size, which is accompanied by a deflation sound and a decrease in its monetary value. At the second simulation part of the trial, a minimal-sized balloon is inflated automatically until it reaches the size that was preset by the participant or explodes if it reaches its explosion point. If the balloon reaches its explosion point, a 'pop' sound is displayed, and participants lose the accumulated money on that trial. Otherwise, they secure the monetary value of the specific balloon. See the online article for the color version of this figure.

value is secured for the participant. If a balloon reaches its explosion point before it reaches the predetermined size, a "pop" sound effect is generated, the monetary gain of the balloon in the specific trial is lost, and a new trial begins with a representation of a fully-sized balloon on the screen.

Importantly, each deflation response at the first size-set part of the trial affected the balloon—a decrease in the size accompanied by a balloon deflation sound. As in the previous experiments, we manipulated the temporal contiguity between the deflation response and both the visual and auditory effects (the deflation effect) by inserting a subtle lag in half of the trials. Specifically, in the Immediate condition, the deflation effect appeared immediately after the deflation response; while in the Lag condition, the deflation effect appeared 450ms after the deflation response (no effectiveness feedback). A predefined list of thirty possible sizes was identical for the two Temporal contiguity conditions. On each trial, the computer selected one balloon from that list in a random order without replacement ($M_{\text{maximum pumps}} = 11.5$, $SD_{\text{maximum pumps}} = 3.67$; Min = 2, Max = 14). Participants performed 30 trials in each condition (overall, 60 trials) that were presented in random order.

Importantly, different from Experiments 1 and 2, we controlled the length of the Immediate and the Lag trials by adjusting the duration of the second simulation part of the trial. Specifically, in the Immediate condition, the duration of the simulation was set to last longer than in the Lag condition by 450ms multiplied by the number of deflation responses in the first size-set part of the trial.

Exactly as in Experiments 1 and 2, at the end of the task, we probed participants' explicit awareness of the manipulation, their perception of whether the manipulation affected their task performance, and the degree they deliberately attempted to apply a risky strategy in the task. Finally, as in the previous experiments, participants completed an electronic version of the Barratt Impulsiveness Scale (BIS-11; Patton et al., 1995).

We predicted that deflation responses will be higher in the Immediate compared to the Lag condition. In addition, we expected that such reinforcing impact of action-effectiveness will be independent of participants' explicit awareness of the manipulation, their perceived influence by it, and their deliberate expectancy-based risk strategy.

## Results

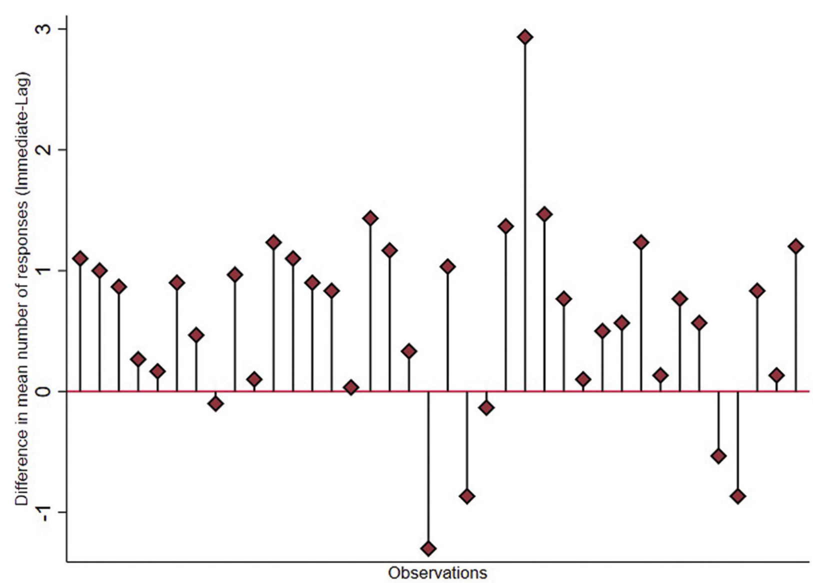
Replicating the findings of Experiments 1 and 2, the number of deflation responses was higher in the Immediate ($M = 9.2$, $SD = 1.4$) compared to the Lag ($M = 8.6$, $SD = 1.47$) condition [$t_{37} = 4.74$, $p < .001$, $CI_{95}$ (.34, .85), $d = .76$, $BF_{10} = 714.2$ (very strong evidence); Figure 5; see also Figure S3 in online supplemental material]. Opposite to the previous experiments and reflecting the nature of the task, the mean number of deflation responses was *negatively* correlated with the number of explosions ($r = -.93$, $p < .001$). Consistently, the number of explosions was lower in the Immediate ($M = 11.47$, $SD = 4.25$) compared to the Lag ($M = 13.71$ $SD = 4.17$) condition [$t_{37} = 5.38$, $p < .001$, $CI_{95}$ (1.39, 3.07), $d = .87$, $BF_{10} = 4414$ (very strong evidence)]. Thus, the findings fully replicate those observed in Experiment 1 in a different context, confirming that 'pure' effectiveness feedback facilitates action tendency which in this task, results in *lower* risk-taking.

### *Explicit Awareness, Perceived Influence, and Deliberate Outcome Expectancy-Based Risk Strategy*

Nineteen participants (50%) were found to be explicitly aware of the temporal contiguity manipulation. A two-way mixed model ANOVA with Explicit awareness as a between-subjects factor and Temporal contiguity as a within-subject factor on the mean number of deflation responses yielded the expected main effect of Temporal contiguity [$F(1, 36) = 21.91$, $\eta 2_{\text{partial}} = .37$, $p < .001$,

**Figure 5**

*Experiment 3: Difference in the Mean Number of Deflation Responses for Each Observation*




*Note.* A value above zero on the y-axis indicates a bias toward the immediate effect over the lagged effect balloons and vice-versa. See the online article for the color version of this figure.

$BF_{10}$ = 519 (very strong evidence)]. An insignificant main effect of Explicit awareness [*F(1, 36)* = 3.16, $\eta2_{partial}$ = .08, *p* = .08, $BF_{10}$ = 1.19 (inconclusive)] was observed. Specifically, deflation responses were nominally lower in the aware (*M* = 8.515 *SD* = 1.58) compared to the Unaware (*M* = 9.29 *SD* = 1.22) group. Critically, no interaction between Explicit awareness and Temporal contiguity [*F(1, 36)* = .03, $\eta2_{partial}$ = .00, *p* = .85, $BF_{10}$ = .23 (conclusive support for the null)] was observed.

Next, we tested whether participants' perception of being influenced by the manipulation affected their actual mean number of deflation responses [14 participants (~37%) believed the manipulation affected their performance]. A two-way mixed model ANOVA with Perceived influence as a between-subjects factor and Temporal contiguity as a within-subject factor on the mean number of deflation responses yielded the expected main effect of Temporal contiguity [*F(1, 36)* = 20.42, $\eta2_{partial}$ = .36, $p < .001$, $BF_{10}$ = 535 (very strong evidence)]. A main effect of Perceived influence [*F(1, 36)* = 7.27, $\eta2_{partial}$ = .16, *p* = .01, $BF_{10}$ = .74 (inconclusive)] was observed. Specifically, participants who believed the manipulation affected their performance tended to have fewer deflation responses (*M* = 8.17, *SD* = 1.23) compared to participants who did not (*M* = 9.33, *SD* = 1.41). Critically, there was no interaction between Perceived influence and Temporal contiguity [*F(1, 36)* = .00, $\eta2_{partial}$ = .00, *p* = .98, $BF_{10}$ = .29 (conclusive support for the null)].

To test whether the Deliberate outcome expectancy-based risk strategy affected their actual risk-taking, we regressed both Temporal contiguity and Deliberate expectancy-based risk strategy score on the mean number of deflation responses ($R^2$ = .25, Root *MSE* = 1.27; adjusted for 38 clusters of participants). Both Deliberate risky strategies [Coef. = -.73, $p < .001$, β = −.46, $CI_{95}$ (−1.1, −.37)] and Temporal contiguity [Coef. = −.59, $p < .001$, β = −.20, $CI_{95}$ (-.85, -.33)] reliably predicted the mean number of deflation responses. Thus, opposite to Experiment 2 and reflecting the nature of the current task, the riskier the strategy participants deliberately took, the *fewer* deflation responses were made. After entering their interaction to the model ($R^2$ = .25, Root *MSE* = 1.28), Temporal contiguity was no longer significant in predicting the mean number of deflation responses [Coef. = −.21, *p* = .63, β = −.07, $CI_{95}$ (−1.11, .68)]. Critically, there was no interaction between Temporal contiguity and Deliberate risky strategy [Coef. = −.1, *p* = .37, β = −.13, $CI_{95}$ (−.33, .12)].

### *Impulsivity: Analyzing Pooled Data From Experiments 1, 2, and 3*

To better estimate the parameter and minimize the risk of insufficient power (Schönbrodt & Perugini, 2013) the following analyses were conducted on pooled data from Experiments 1, 2, and 3 (n = 142; see online supplemental material for data analyses of the individual experiments). We found a small correlation between the mean impulsivity score and the adjusted mean number of pumps (*r* = .18, *p* = .024). Next, we tested whether action-effectiveness interacted with impulsivity trait level to affect action-tendency. Participants were assigned to High (above 1*SD*), Medium (between −1*SD* and 1*SD*) or Low (bellow −1*SD*) impulsivity groups (*M* = 65.60, *SD* = 10.51). A two-way mixed model ANOVA with Impulsivity as a between-subjects factor and Temporal contiguity as a within-subject factor on the adjusted mean number of pumps yielded a main effect of Temporal contiguity [*F(1, 139)* = 28.43, $\eta2_{partial}$ = .17,
$p < .001$, $BF_{10}$ = 9.521e + 7 (very strong evidence)] and no main effect of Impulsivity [*F(2, 139)* = 1.68, $\eta2_{partial}$ = .02, *p* = .18, $BF_{10}$ = .6 (inconclusive)]. Note, however, consistent with the small correlation between impulsivity score and the adjusted mean number of pumps, a pairwise comparison with Tukey correction for multiple comparisons between the high and low impulsivity groups on action tendency was statistically significant [*p* = .048, $CI_{95\%}$ (.01, 4.41); no other comparisons were significant]. Importantly, no interaction was observed between Impulsivity and Temporal contiguity [*F(2, 139)* = .91, $\eta2_{partial}$ = .01, *p* = .40, $BF_{10}$ = .16 (substantial support for the null)].

## General Discussion

In the present article, we tested whether independently of expected value, risk-taking is influenced by immediate versus delayed action effects. In the two first experiments, we largely replicated the findings of Damen (2019), demonstrating that immediate effects increased risk-taking measured by the Balloon Analogue Risk task (BART). However, as increased action tendencies and increased risk-taking are confounded in the BART, we conducted a crucial third experiment for which we developed an inverse version of the BART (iBART) in which increased action tendencies led to lower risk-taking. This experiment demonstrated that immediate versus delayed action-effect increases action tendencies in general, which may lead to increased or reduced risk-taking, depending on the task.

The current work is in line with theoretical (Higgins, 2012; Karsh & Eitam, 2015b; Wen, 2019; White, 1959) and empirical (Behne et al., 2008; Eitam et al., 2013; Hemed et al., 2020; Karsh et al., 2015a; 2016; 2020; Penton et al., 2018) advances in identifying the motivating impact of mere action-effectiveness. Specifically, previous work on how action's effectiveness is determined within the motor-system (compared to the higher-level cognitive system; Karsh & Eitam, 2015b; for a relevant review see Wen, 2019) highlights its sensitivity to subtle physical discrepancies or prediction errors (e.g., delays) between action and action-effect (Blakemore et al., 1999; Haggard et al., 2002; Karsh et al., 2016), as manipulated in the current study. According to the CBRS framework (Karsh & Eitam, 2015b), perceptual effects that are contingent and temporally contiguous on one's action (e.g., produces minimal prediction errors) are themselves, rewarding (see also, Behne et al., 2008) and accordingly, motivate further control-effective actions (for a developmental work see, Watanabe & Taga, 2006); whether through increasing stimulus-response association (Tanaka et al., 2021) or by crediting control-effective actions with higher control-value (Karsh & Eitam, 2015b). Based on this logic, we suggest that the observed reinforcement may be grounded within the motor system and as such, it is modulated by the temporal contiguity of the effect with the action.

The current study does not rule out the potential for action-effects to be subjected to cognitive evaluations regarding its nature that may also affect behavioral decisions outside the motor system (Karsh et al., 2015a, 2015b). However, in the current study, we found no indication for such indirect route as the reinforcing impact of action-effectiveness held regardless of the impact participants' deliberate expectancy-based risk strategy on action tendency or their explicit recognition of the manipulation. These findings are seemingly at odds with a recent study by Damen

(2019) who demonstrated that explicit reports of perceived risk-control over the balloons mediated the effect of the delay manipulation on the number of pops in the BART, but not the number of pumps. As pops were determined by the number of pumps plus a random component, the mediating role of an experienced agency may perhaps be explained differently: Participants could have reported lower experiences of control after trials on which their balloon popped. In the current study (Experiments 1 and 2) we found no evidence for a difference in the effect as a result of explicit knowledge regarding the manipulation and participants' deliberate risk-strategy which suggests that the effect can emerge independently of deliberate processes.

## Impulsivity

Pooled data from all three experiments were used to explore whether participants' impulsivity trait levels interacted with action-effectiveness to influence action tendency. Our (admittedly speculative) rationale here was that high impulsivity levels may be associated with increased sensitivity to action-effectiveness. We based this speculation on previous work suggesting close theoretical and empirical relations between sensation-seeking behavior (e.g., need for stimulation) and impulsivity (e.g., Carrol et al., 1982) and on daily observations in which impulsive behaviors seem to emerge even when outcome expectancy is negative (e.g., impulsively punching the wall out of frustration). Different from our expectations, the findings provide substantial support for the null hypothesis. Note, however, the findings from the three experiments together, provide some support that individuals with high (compared to low) impulsivity levels, as measured by the BIS-11 (Patton et al., 1995) have a higher action tendency in general. The findings encourage future work to focus on the exact mechanistic nature of impulsivity and its measurements and to clarify its relationship with both action tendency and risky decision making (e.g., Reynolds et al., 2006; see also; Vigil-Colet, 2007; ).

## Potential Limitations and Future Studies

Potential limitations of this study should be noted. In Experiments 1 and 2 the length of the trial was not controlled between the two Temporal contiguity conditions. Thus, one may argue that participants were willing to make more pump responses in the Immediate condition because they were quicker. Importantly, however, Damen (2019) controlled for such discrepancy between the two conditions and still obtained the same effect on the adjusted mean number of pumps. In addition, as mentioned above, we attempted to minimize participants' urgency to finish the experiment and their potential attempts to inflate more balloons by presenting the experiment duration to be longer than it lasted and by informing them that the number of balloons to be inflated is fixed. Critically, in Experiment 3 we directly controlled the length of the trial in the two conditions by adjusting the duration of the simulation part of the trial so that in the Immediate condition, it was set to last longer than in the Lag condition by 450ms multiplied by the number of deflation responses in the first size-set part of the trial. Importantly, the pattern of results obtained in Experiments 1 and 2 was fully replicated in Experiment 3.

Second, it should be noted that because no baseline condition was applied (e.g., a No-effect condition) in the current study, one may argue that the lagged effect decreased participants' tendency to act rather than that the immediate effect increases their tendency to act (for a relevant review see, Wen, 2019). However, in our previous work, we used a No-effect condition in a between-subjects design and demonstrated that both response times and response frequency are facilitated in the Immediate effect compared to a No-effect condition (Eitam et al., 2013; Karsh & Eitam, 2015a; Karsh et al., 2016). Thus, because in our previous studies mentioned above we used a between-subjects design (each participant experiences a different Effect condition and was unfamiliar with the other Effect conditions), the No-effect condition in these previous studies can be referred to as a baseline condition.

## Implications

Although we have no reason to believe that the reinforcing impact of action-effectiveness is unique to undergraduate students, a differential weighting mechanism of the two reinforcers, action-effectiveness and outcome expectancy can be used as a promising framework to study individual differences in risk-taking behavior. It may also contribute to understanding behavioral dynamics along the course of development and in clinical conditions such as ADHD. Thus, we encourage future developmental work to systematically investigate the two independent sources of motivation (action-effectiveness and outcome expectancy) across the life span, focusing on the distinct functions they serve in real-life situations (e.g., Watanabe & Taga, 2006; 2011).

The current work joins previous studies demonstrating BART's limitations by specifying factors that may influence participants' scores on the BART other than their willingness to take risks. For instance, in an attempt to improve BART's psychometric properties and its relation to real-life risky behaviors (e.g., alcohol consumption; Pleskac et al., 2008), the authors minimized learning across the task by informing participants about the optimal number of inflations. In addition to learning requirements that may influence BART scores, a recent article demonstrated that the usual uniform distribution of explosion points may differ from participants' expectation from a real balloon and accordingly, can affect their behavioral decisions in the task (Steiner & Frey, 2021). The current study adds to the above literature by highlighting the role of action-effect temporal contiguity in promoting action-tendency in general rather than risk-taking. While impulsivity and BART scores are only modestly correlated, it seems that action-tendency has a larger influence on BART scores than previously thought. While action-tendency can potentially increase risk-taking (as in the original BART), our iBART shows that action-tendency can also decrease risk-taking. In practice, a combination of the original BART with our iBART in future studies may help researchers to elucidate variability in BART scores that is not related to mere action-tendency and potentially more closely related to impulsive risky behavioral decisions.

To summarize, different from popular outcome expectancy-based models (e.g., Williams et al., 2005), the current study provides strong evidence that exercising control by having an own-action effect can facilitate both risky and cautious behavior. As such, higher scores on this task may reflect a motivation for action and not necessarily risk-taking. In daily life, it may be the case that immediate feedback on their actions may make people more prone to act, but this could either lead to more risky or more cautious behavior. As such, motivation for action should not be confused with taking a risk.

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