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Loss attention in a dual task setting

Eldad Yechiam
Technion – Israel Institute of Technology

Guy Hochman
Duke University

Abstract

The positive effect of losses on performance has been explained as due to the increased weighting of losses compared to gains. We examine an alternative approach whereby this effect is mediated by attentional processes. Using the dual task paradigm, it was expected that positive effects of losses on performance would emerge under attentional scarcity, and diffuse to a concurrently presented task. In Study 1, decision performance was compared for a task involving gains or losses, when it was performed alone or as a secondary task. The results showed a significant 40% improvement in performance in the loss condition, but only under resource scarcity, when the task was secondary. In Study 2 the same task was presented as a primary task. Again, losses were associated with improved performance in the secondary task. Since this secondary task did not include losses, these findings demonstrate an attentional spillover effect.

Keywords: loss; attention; decision making; performance; search behavior.

Corresponding author: Eldad Yechiam, Max Wertheimer Minerva Center for Cognitive Studies, Faculty of Industrial Engineering and Management, Technion - Israel Institute of Technology, Haifa 32000, Israel. Phone: (972) 4-829-4420, Fax: (972) 4-829-5688, Email: yeldad@tx.technion.ac.il . This work was supported in part by the Max Wertheimer Minerva Center for Cognitive Studies.

In one of Jorge Luis Borges stories (“The Babylon lottery”, 1941), he describes a society in which merchants have invented a lottery where winners receive silver coins and other rewards. However, the public remains indifferent to this lottery system. Then “someone attempted to introduce a slight reform: the interpolation of a certain small number of adverse outcomes among the favored numbers”. This leads to immense popularity and eventually the loss-based lottery becomes mandatory for all citizens. Borges’ tale appears to capture the exhilaration triggered by the prospect of losing and its potential for elevating attention and excitement. Modern studies have indeed shown that embedding losses within a cognitive task increases physiological arousal (e.g., Bechara, Damasio, Tranel, & Damasio, 1997; Satterthwaite, et al., 2007; Löw, Lang, Smith, & Bradley, 2008; Hochman & Yechiam, 2011) and enhances performance (e.g., Costantini & Hoving, 1973; Denes-Raj & Epstein, 1994; Bereby-Meyer & Erev, 1998; Dawson, Gilovich, & Regan, 2002; Maddox, Baldwin, & Markman, 2006; Pope & Schweitzer, 2011; Saguy & Kteily, 2011; Hossain & List, 2012). We recently proposed that these two effects are interlinked: the increased arousal following losses marks an increase in attentional investment, which in turn results in enhanced performance in some settings (Yechiam & Hochman, 2013a). The goal of the current paper was to examine in a direct fashion whether the increased allocation of attention to tasks with losses mediates their effect on performance.

A dominant view attributes the effect of losses on performance to loss aversion (e.g., Bereby-Meyer & Erev, 1998; Erev & Barron, 2005; Pope & Schweitzer, 2011; Hossain & List, 2012), the notion that losses have greater subjective weight than equivalent gains (Kahneman & Tversky, 1979). For example, in a recent field experiment Hossain and List (2012) used monetary incentives framed as gains (gain y by doing x) or losses (avoid losing y by doing x) to increase workers’ productivity in a real factory. While both of these types of incentives increased productivity, the magnitude of the effect of loss framing was larger by about 15%. Hossain and List (2012) explained this difference as due loss aversion, which should result in increased tendency to perform above criterion level so as to avoid losses. By contrast, under the alternative "loss attention" model (Yechiam & Hochman, 2013a; 2013b) losses draw more attention to the task. Consequentially, they increase workers' sensitivity to the task incentive structure.

While in studies such as Hossain and List's (2012) the two accounts for the effect of losses cannot be disentangled, several previous findings indirectly support the role of attention as a mediator for the effect of losses on performance: First, while the positive effect of losses on performance was found in conditions where loss and gain tasks were administered in a between subject design (as in Hossain & List, 2012), it was not observed in a within-subject design where gain and loss tasks were administered intermittently (e.g., Magoon & Critchfield, 2008; Ruddle, Bradshaw, & Szabadi, 1981).[1] Secondly, losses were found to have a positive effect on performance even in situations where high performance results in greater losses (Yechiam & Hochman, 2013b). Both sets of findings suggest that losses affect performance through increased general arousal and attention rather than increased weighting of loss compared to gain outcomes. Still, these previous studies provide only indirect evidence for the mediating role of attention.

To examine whether the effect of losses on performance stems from their impact on attentional processes we employed the dual task paradigm, often used in attention research (see Kahneman, 1973; Navon & Gopher, 1979; Wickens, 2002). Following Kahneman's (1973) seminal work, our basic premise was that changes in attention occur in two different levels: the overall attentional resource pool (see also Young & Stanton, 2002), and the relative allocation of that pool between concurrent tasks. Based on the loss attention model (Yechiam & Hochman, 2013a), we further assumed that losses in a given task mainly increase the overall

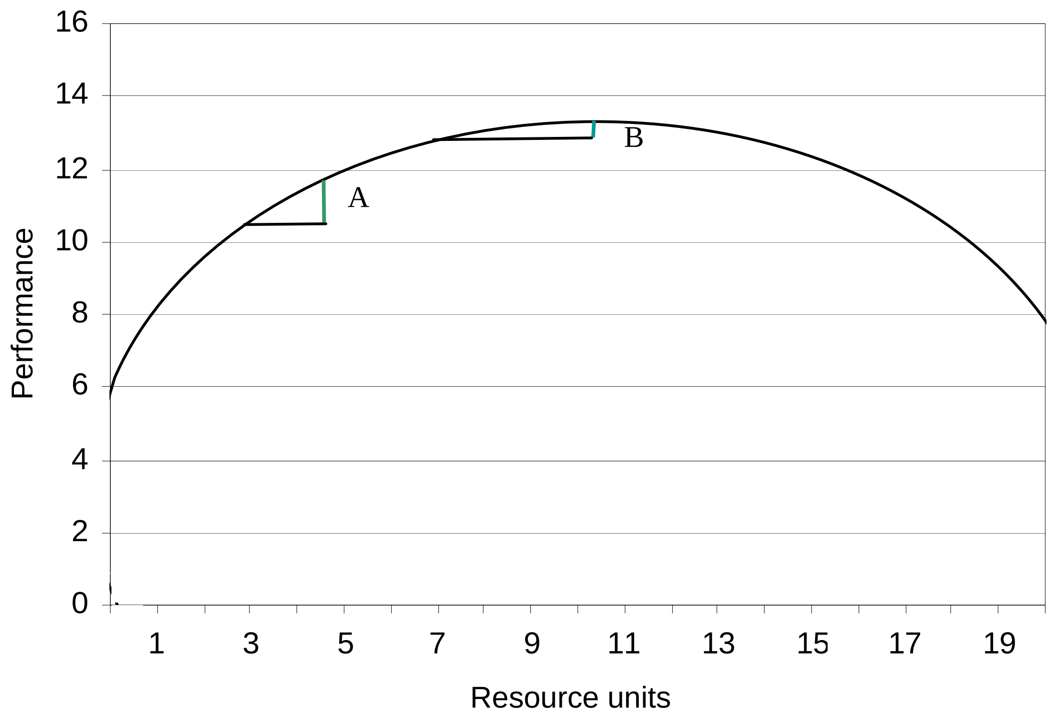
[1] The null findings in the latter setting were suggested to be due to the slow decay of the attentional investment following losses, which leads to an effect of losses on performance in tasks preformed subsequentially to experiencing losses (Yechiam & Hochman, 2013a).

attentional resource pool available for the task, leading to a inverse-U shape effect on performance (following the so called Yerkes-Dodson law; see Kahneman, 1973).

The implication of this model to the effect of losses on performance can be demonstrated using the following numerical example. Consider a resource limited task (Norman & Bobrow, 1975; Navon & Gopher, 1979) where additional resources can improve performance. Our model might posit 10 units of resources available when gains are involved, which are distributed 7:3 for the primary and secondary tasks, respectively. If the task is changed to include losses, the available supply increases (e.g., by a factor of 1.5) without changing the relative allocation of the pool between concurrent tasks. Hence, the allocation in this loss condition would be 10.5:4.5, with the primary task gaining more resource unit (3.5 compared to 1.5). However, as demonstrated in Figure 1, our model suggests that losses would nevertheless have a larger effect on performance in the secondary task than in the primary task because of the diminishing marginal benefit of investment implied by the Yerkes-Dodson law.

This model leads to three specific predictions. First, losses are expected to have more effect on performance in a dual-task setting were attentional resources are depleted (e.g., due to strict time limitations) than in a single or dual task setting where resources are abound. Secondly, due to the shape of the function (see Figure 1), this effect should be stronger for a secondary than for a primary task. Thirdly, losses are predicted to affect performance in a global manner such that losses in one task could improve performance in a different task. Specifically, if losses are part of a primary task, this is expected to increase overall task attention. As noted above, this should have little effect on primary task performance, but could substantially affect performance in the secondary task even if it does not include losses. More generally, this would be an instance of a spillover effect, where stimuli in one task affect performance in a conjoined task (see Navon & Gopher, 1979; Lavie & Torralbo, 2010; Swallow & Jiang, 2013).

Figure 1: A hypothetical graph for the increase in performance as a function of attentional resources. Line A denotes the performance improvement from 3 to 4.5 resource units and line B denotes the performance improvement from 7 to 10.5 units. Despite the similar rate of increased resources (1.5), performance improvement is larger for the resource-lean position.



Study 1: Losses in a Secondary Task

In this study we examined whether the effect of losses on decision performance is amplified when they are part of a secondary task. The basic task we used involved repeated selections between two choice alternatives, where one alternative is advantageous in terms of expected value. Hence, high performance implies selecting the advantageous option and increasing earning.

The payoffs contingent upon selecting alternatives were drawn from the following distributions:

Problem 1. Gain Condition:

L: Win 15 + Noise

H: Win 17 + Noise

Problem 1. Loss condition:

L: Lose 17 + Noise

H: Lose 15 + Noise

In each condition, one alternative (H=High) had higher expected value than the other (L=Low), To make the incentive structure less transparent, we added a noise factor, which was randomly drawn from the outcomes: -4, -3,-2, -1, 0, 1, 2, 3. The task involved 100 trials, with the final payment for the experiment being based on the accumulated reward. Participants were not told in advance that one alternative has higher expected value. Rather, they were expected to find this through feedback (as in Erev & Barron, 2005). In the Loss condition the fixed outcome in each choice alternative was multiplied by -1 while the noise factor remained the same.

In the *Single-task* condition participants performed only Problem 1 as a two-alternative decision task. Participants were required to make each selection in three seconds (per trial). Previous findings suggest that response time in this type of tasks is quite short (typically less than 2 seconds; Yechiam & Telpaz, 2013). We therefore assumed that a time limit of three seconds would result in no scarcity of attentional resources. Hence, we predicted only a limited effect of losses on performance in the Single-task setting.

By contrast, in the *Dual-task* condition participants performed two tasks, each requiring a separate decision, under the same three-second limitation. In attention research sometimes participants are told which task is the primary and which is the secondary. In other studies this hierarchy is implicitly implemented by having a primary task with higher payoffs than in the secondary task (see e.g., Gopher, Weil, & Siegel, 1994). We used the latter design as follows:

Problem 2 (Primary task):

H: 0.7 probability to obtain 150, otherwise get 0

L: 0.5 probability to obtain 150, otherwise get 0

As can be seen, in this choice problem as well, one alternative (H) has higher expected value than the other (L). However, the difference between alternatives in this problem lies not in the payoff magnitude but rather in the probabilities involved (this was implemented so as to minimize transfer of learning from the concurrently performed Problem 1). Also, the incentives in this task are substantially higher (by a factor of 10) than in Problem 1, resulting in a larger expected difference between alternatives. Hence, we expected that participants would prioritize Problem 2 (the primary task) over Problem 1 (the secondary task). Therefore, under our model, within the Dual-task setting performance in Problem 1 (the secondary task) was expected to improve in the Loss condition compared to the Gain condition.

Method

Participants:

Eighty-eight Technion undergraduates (44 males and 44 females) were recruited through email notices for an experiment yielding NIS 15 to NIS 35 (NIS 1=$4.2). The participants' average age was 25.0 years, ranging from 20 to 33. Participants were randomly allocated to the Single and Dual-task conditions, and within these conditions to the Gain and Loss conditions (Single-task Gain n=23, Loss n=21; Dual-task Gain n=22, Loss n=22). Their payoff consisted of a fixed fee of NIS 20 and a variable fee contingent on task performance.

Task:

Single-task condition: The participants' instructions were as follows: "In this experiment you will perform a decision making task. Your basic fee is NIS 20. This payment will be updated based on your accumulated winnings at a rate of NIS 1 per 1,000 game points. In the screen in front of you there will be two buttons, A and B. Your task is to select between these buttons by pressing one of the buttons. You can press a button multiple times (as many times as you want) or switch between buttons (as much as you want). In each trial you will see the outcome from the selected button and from the unselected button, as well as the accumulating sum. In each trial you will have 3 seconds to respond once you see the outcomes. Please notice that your outcome in a given trial is only affected by the current trial and not by past trials." An illustration of the task appears in Figure 2.

After making each choice, payoffs from the selected and unselected buttons were presented for one second. During this one second the participants could not press the buttons (buttons were colored red and disabled). Then participants had three seconds to make their next selection. The accumulated payoff was presented constantly. The payoffs in each trial were contingent upon the button chosen and were randomly drawn from the relevant distributions of Problem 1 (depending on the experimental condition). The allocation of alternatives L and H to buttons A and B was randomized for each participant and was kept constant throughout the task. The dependent measure was the rate of H selections in the first and second blocks of trials.

Dual-task condition: In this condition after stating the basic fee as above, participants were told as follows: "In the screen in front of you there will be four buttons, A, B, C, and D. You have two tasks: To select between buttons A and B (the top buttons) and to select between buttons C and D (the bottom buttons). In each trial you will have to perform both tasks by selecting one button in each pair." The remaining instructions were as in the Single-task condition. An illustration of the task appears in Figure 3. Payoffs for the top task were drawn from Problem 2 (the primary task) and payoffs for the bottom task were drawn from Problem 1 (the secondary task). Participants had a 3 second response-time limitation (as in the Single-task condition) to make selections in both decision tasks. Again, the main dependent variable was the rate of H selections in Problem 1.

Figure 2. The experimental screen in the Single-task condition of Study 1.

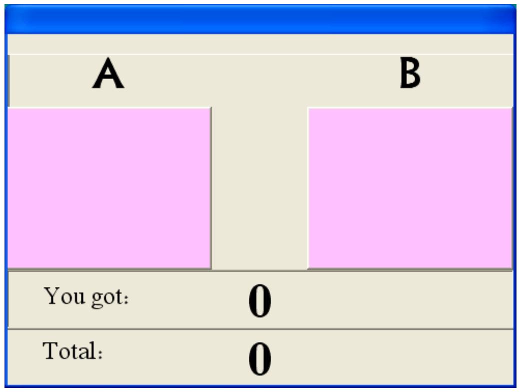
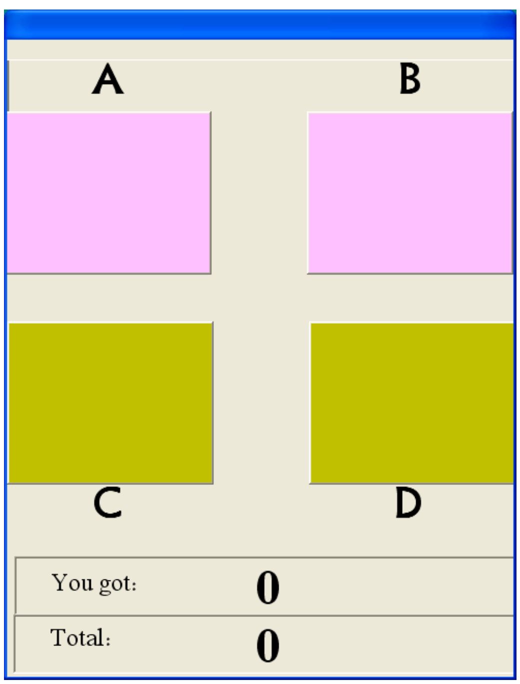


Figure 3. The experimental screen in the Dual-task condition of Study 1 (and in Study 2).



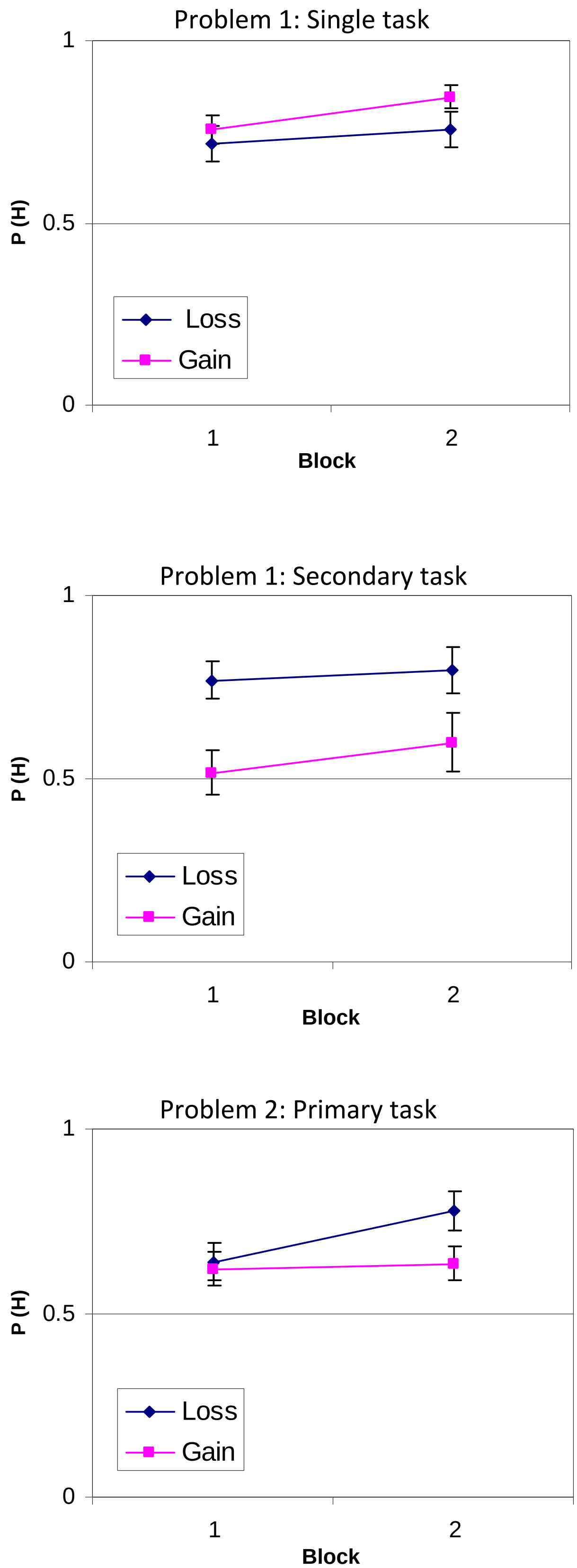
Participants in all conditions were given an initial practice session with the goal of learning to respond in a timely manner. Not responding within time limit resulted in a loss of 200 points. The practice session used a simple task with one alternative producing a constant of 100 and the other producing 0. Following this practice task, the rate of no-response trials in the actual task was very low (4.0%).

Results

Figure 4 presents the selection rates from the advantageous alternative H in the first and second blocks of the task. As can be seen, within the Single-task condition, the overall rate of H selections (P(H)) in Problem 1 was similar in the Gain and Loss conditions (P(H) Gain=0.81, P(H) Loss=0.73). As predicted, a much larger positive effect of losses on performance appeared in the Dual-task condition (P(H) Gain=0.56, P(H) Loss=0.79), in which losses increased performance in this decision problem by 40%.

To examine the statistical significance of the results, we conducted a mixed analysis of variance, with valence (Gain versus Loss) and task (Single-task versus Dual-task) as between subject factors, and trial block as a within subject factor. The results showed a significant positive effect of trial block ($F(1,84)=8.24$, $p=.005$), and task ($F(1,82)=4.24$, $p=.04$) on performance, but no main effect of valence ($F(1,84)=2.19$, $p=0.14$). Most importantly, however, there was a significant interaction of valence and task ($F(1,84)=8.90$, $p=0.004$). Planned contrasts with Bonferroni corrections showed that within the Single-Task setting the difference between the Gain and Loss conditions was not significant ($F(1,42)=2.18$, $p=0.29$). The difference was only significant in the Dual-Task condition ($F(1,42)=6.73$, $p=0.02$). Hence, losses only led to higher performance than equivalent gains when Problem 1 was performed as a secondary task.

Figure 4. Study 1 results. Mean proportions of selections from the high expected-value alternative (H) in Problems 1 and 2. In the Single-task condition Problem 1 was the only task performed, while in the Dual-task condition it was the secondary task (while Problem 2 was the primary task). The error bars denote the standard error.



We also examined the effect of losses on performance in Problem 2, the primary task in the Dual-task condition. Since the primary task was not assumed to benefit much from additional resources (see Figure 1), losses were not expected to considerably affect its performance. The results showed that in this task the rate of H selections was 0.63 (±0.13) in the Gain condition and 0.71 (±0.05) in the Loss condition (a 12% improvement). The ANOVA results indeed showed no main effect of valence ($F(1,42)=1.53$, $p=0.22$). However, the interaction between valence and trial block was significant ($F(1,42)=11.16$, $p=0.002$), as in the second block of trials losses in the secondary task improved performance in the primary task as well ($t(42)=2.04$, $p=.047$).

We further examined whether improved performance in the secondary task was associated with better performance in the primary task at the individual level as well. In the Loss condition there was a high positive correlation between performance in the primary and secondary tasks ($r=0.75$, $p<0.001$). By contrast, in the Gain condition the correlation between performance in these two tasks was weak and non-significant ($r=0.15$, $p=0.52$). Hence, rather than creating a tradeoff between the primary and secondary tasks, losses in the secondary task appeared to increase the consistency with which effort was allocated to the two tasks.

To verify that the scarcity of resources contributed to the effect of losses on secondary task performance, we replicated the Dual-task condition with no penalty for going beyond the 3-seconds time constraint (participants just did not get any points for that trial). The replication study involved 48 participants, 24 males and 24 females. In this setting the rate of trials in which the time limit was exceeded was rather high: 23% compared to 4% in the original experiment. In accordance, mean response times were longer: Gain: 2.97±0.10 s, Loss: 3.05 ±0.07 s; compared to Gain: 2.27±0.11 s, Loss: 2.40±0.15 s in the original experiment. Also, the distribution of response time was more skewed, with a mean maximal response time of 12.7±2.11 s per trial compared to 3.3±0.34 s in the original Dual-task condition. Hence, participants had considerably more time to perform the secondary task (Problem 1). As expected, in this case performance levels in the secondary task were similar in the Gain and Loss conditions (Gain $P(H)=0.74\pm0.07$, Loss P(H)=0.66±0.07; see Supplementary Materials). Namely, the performance advantage induced by losses only appeared in the original study where time limitations were enforced.

Study 2: Losses in a Primary Task

In this study we examined the effect of losses in a primary task on performance in a secondary task. It was expected that the increase in overall attention due to losses in the primary task, would mostly affect performance in the resource-depleted secondary task. The primary task was Problem 1, with the same Gain and Loss conditions as in Study 1. The secondary task was a variant of Problem 2 in which we divided each outcome by 1,000, creating very small monetary amounts, as follows:

Problem 3 (Secondary task):

H: 0.7 probability to obtain 0.15, otherwise get 0

L: 0.5 probability to obtain 0.15, otherwise get 0

We expected that losses in the primary task would lead to increased performance in this secondary task.

Method

Participants:

Forty-eight Technion undergraduates (24 males and 24 females) participated in the experiment. Their average age was 24.0 years, ranging from 17 to 32. Participants were randomly allocated to the Gain and Loss conditions (n=24 in each condition). As in Study 1, participants' payoff consisted of a fixed fee of NIS 20 and a variable fee based on task performance.

Task:

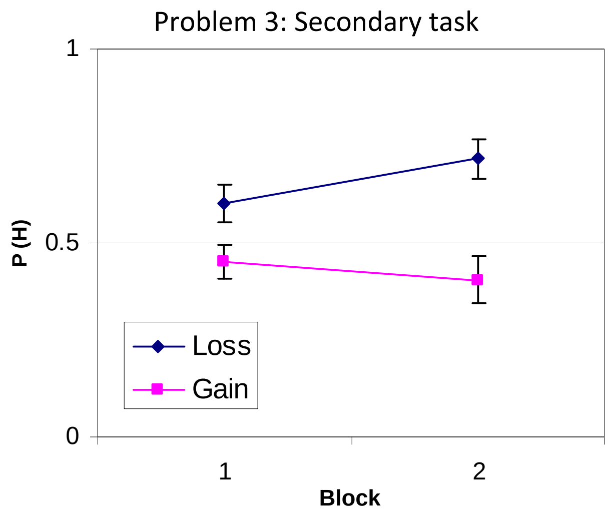
The recruitment protocol, experimental task, and instructions were identical to those in Study 1 (see also Figure 3). The only difference is that payoffs for the topmost buttons were now sampled from Problem 1, while payoffs for the bottom buttons were sampled from Problem 3.

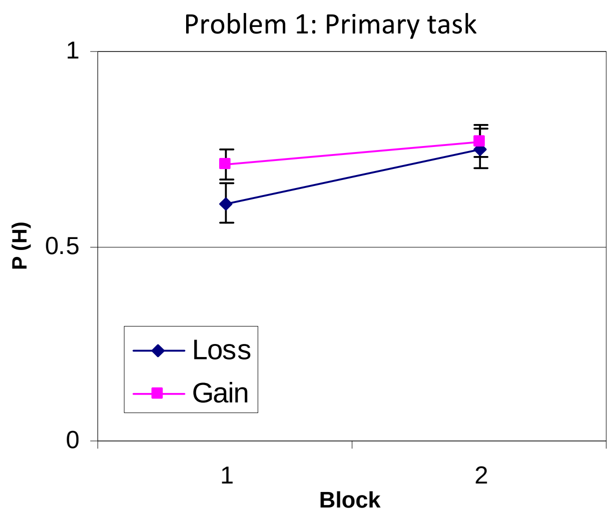
Results

The selection rates from the advantageous alternative H in the primary and secondary tasks appear in Figure 5. Within Problem 1, the primary task in terms of payoff magnitude, there was no significant difference between the Gain and Loss conditions ($F(1,46)=1.09$, $p=0.30$) or interaction between trial block and condition ($F(1,46)=2.88$, $p=0.10$). Hence, losses did not significantly affect performance in this task. However, losses in the primary task had a substantiate positive effect on performance in the secondary task (Problem 3; $F(1,46)=12.10$, $p=0.001$). Performance in this task increased in the Loss condition by about 53% (P(H) Gain=0.43, P(H) Loss=0.66). In addition, there was a significant interaction of condition by trial block ($F(1,46)=7.16$, $p=0.01$) showing that the effect of losses on performance increased over time. Thus, losses in the primary task improved performance in the secondary task.

We also examined whether at the individual level performance in these two tasks was related. In the Loss condition the correlation between performance in the primary and secondary task was extremely high and significant ($r=0.91$, $p<0.001$). By contrast, in the Gain condition the correlation was near zero ($r=-0.16$, $p=0.45$).

Figure 5. Study 2 results. Top: Mean proportions of selections from the high expected-value alternative (H) in Problem 3 (the secondary task in this study). Bottom: Mean proportions of selections from H in Problem 1 (the primary task). The error bars denote the standard error.





Discussion

In two studies we have found evidence that attentional processes modulate the effect of losses on cognitive performance. In Study 1, losses did not significantly affect performance in a decision task performed with no additional concurrent requirements. When the very same task was presented as a secondary task in a setting where participants performed two tasks within a limited time, the same losses led to a substantial (40%) improvement in task performance. Hence, losses appear to improve performance in the classic setting of depleted attention (Navon & Gopher, 1979).[2] Losses in the secondary task also led to a small (12%) improvement in the concurrently performed primary task, which was significant at the second half of the task. Though we did not expect this interaction it is consistent with our proposition that the effect of losses is to expand the overall resource pool, and thus losses in a secondary task can affect performance in the primary task as well.

In Study 2, the secondary task in the previous study (Problem 1) was used as a primary task in a dual task setting. The results showed that losses did not affect performance in this task. Instead, in this study there was a positive effect of losses on the concurrently performed secondary task (involving only gains). Thus, losses led to an attentional spillover from the primary to the secondary task, resulting in improved performance in the secondary task. This further attests that within a dual task setting losses enhance performance in the resource lean secondary task.

The individual differences findings in Study 1 and 2 provide another level of analysis demonstrating the attentional effect of losses. In both studies, the administration of losses resulted in much higher correlations between performance levels in the primary and secondary task. Specifically, increased performance in the task with losses was associated with increased performance in the concurrently performed task that did not include losses. It therefore appears that at the individual level as well, the allocation of attention and increased performance due to losses is not a local phenomenon, but one which affects global task performance. It is interesting to speculate on the mechanism responsible for this pattern of individual differences. One possible contributor is individual differences in peoples' sensitivity to negative stimuli (e.g., Higgins, 1997; Maddox et al., 2006). The increased sensitivity to losses of some participants may have contributed to their elevated global performance level on the face of losses. Another possibility,

[2] One limitation of the current studies is that because learning did not reach a plateau (see supplementary Figure 2) we could not analyze the participants' performance strategies.

though, is that in the Loss condition successful performers generalized their strategy of performance better from one task to the other. Consequentially, those with superior performance in the task with losses also performed better in the concurrent task that did not include losses.

The complete absence of an effect of losses on performance in the one-task setting of Study 1 appears to be inconsistent with the results of studies who found a positive effect of losses in a single-task setting (e.g., Costantini & Hoving, 1973; Denes-Raj & Epstein, 1994; Bereby-Meyer & Erev, 1998; Hossain & List, 2012; Maddox et al., 2006; Pope & Schweitzer, 2011). Yet note that differently from these studies, in the Loss condition of Study 1 participants could not avoid sustaining losses. This might have led some participants to experience learned helplessness (Maier & Seligman, 1976), thereby reducing the positive effect of losses on performance (see Yechiam & Hochman, 2013). Additionally, some of the abovementioned studies involved tasks with considerable attentional requirements (e.g., Costantini & Hoving, 1973; Hossain & List, 2012; Pope & Schweitzer, 2011). For instance, Pope and Schweitzer (2011) and Hossain and List (2012) focused on real-world tasks (golfing, production and inspection) where participants have off-task distractions that may carry attention away from the main task and thus increase the positive effect of losses on performance. Our results therefore do not necessarily contradict these previous findings. Rather, they serve to highlight an inherent condition (attentional scarcity) that makes cognitive tasks susceptible to the positive effect of losses.

Conclusions

The most common explanation for the effect of losses on performance invokes the construct of loss aversion. Some argue that loss aversion only entails a utility asymmetry between gains and losses (Kahneman & Tversky, 1979), while others argue for a multi-faceted process involving utilitarian as well as attentional asymmetries (Baumeister et al., 2001; Taylor, 1991). We have demonstrated that in a dual-task setting, an attentional effect is a necessary and sufficient condition to understand the effect of losses. With no attentional constraints, when a task was performed singly, losses had no effect on performance. By contrast, in both our studies the most substantial effect of losses on performance occurred in a setting involving limited resources where the (loss or gain) choice task was secondary.

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