Framing and Self-Responsibility Modulate Brain Activities in Decision Escalation

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Abstract

Background: Escalation of commitment is a common bias in human decision making. The present study examined (1) differences in neural recruitment for escalation and de-escalation decisions of prior investments, and (2) how the activation of these brain networks are modulated by two contextual/confounding factors: (i) responsibility, and (ii) framing of the success probabilities.

Results: Imaging data were obtained from functional magnetic resonance imaging (fMRI) applied to 29 participants. A whole-brain analysis was conducted to compare brain activations between conditions. ROI analysis, then, was used to examine if these significant activations were modulated by two contextual factors. Finally, mediation analysis was applied to explore how the contextual factors affect escalation decisions through brain activations. The findings showed that (1) escalation decisions are faster than de-escalation decisions, (2) the corresponding network of brain regions recruited for escalation (anterior cingulate cortex, insula and precuneus) decisions differs from this recruited for de-escalation decisions (inferior and superior frontal gyri), (3) the switch from escalation to de-escalation is primarily frontal gyri dependent, and (4) activation in the anterior cingulate cortex, insula and precuneus were further increased in escalation decisions, when the outcome probabilities of the follow-up investment were positively framed; and activation in the inferior and superior frontal gyri in de-escalation decisions were increased when the outcome probabilities were negatively framed.

Conclusions: Escalation and de-escalation decisions recruit different brain regions. Framing of possible outcomes as negative leads to escalation decisions through recruitment of the inferior frontal gyrus. Responsibility for decisions affects escalation decisions through recruitment of the superior (inferior) gyrus, when the decision is framed positively (negatively).

Background

Decision escalation, sometimes called escalation of commitment, refers to a common sunk cost bias in decision making, whereby the decision maker takes into account irrelevant prior information regarding an investment (time, money and/or effort) and consequent emotions, for making future decisions (Staw, 1976). Under such circumstance, the mere fact that an investment was made increases the likelihood of further investment, even though it may not be the optimal decision. For example, people may continue investing in a failed project (or stand in a long line at a store), even though the best path forward may be to quit the project (or move to a different line), just because they have already invested in the project (or already spent time standing in one line) (Thaler, 1980). This decision escalation effect is prevalent; for example, 54% of consumers in one experiment chose a trip based on sunk cost and not its utility (Arkes & Blumer, 1985). This phenomenon has two characteristics that reflect bias rationality (Jessup, Assaad, & Wick, 2018). The first is the biasing of decisions such that they are more persistent with prior choices, even when other information may suggest other optimal paths. The second is the violation of the principle of stochastic dominance. When one choice never pays less and can stochastically pay more than a second option, it is stochastically dominant. Two studies have shown that sunk cost can increase the chance of violating this principle when the expected value is low (Jessup, Assaad, & Wick, 2018).

It is important to study the roots of this bias and the contextual factors that may modulate it, because this understanding can underlie correcting decision-making in various contexts, such as continued investment in failed projects (Keil et al., 2000). This knowledge has also clinical significance, because decision escalation bias may be accentuated in people with impulse control disorders (Monterosso & Ainslie, 1999) including for instance, in gamblers (Rogers, 1998). We hence seek to expand current knowledge regarding decision escalation bias, and specifically regarding the brain regions that are recruited for escalation and de-escalation decision, under different responsibility and framing conditions. It is important to consider escalation and de-escalation decisions independently, because the brain can encode rewarding and punishing outcomes differently(Jessup & O'Doherty, 2014); it is reasonable to view escalation decisions as generating reward expectations, and de-escalation decisions as generating certain loss/punishment expectations.

Recent research has pointed to key neural mechanisms underlying this bias. Specifically, It was found that different networks are sensitive to the sunk cost (already invested) amount, and to the incremental (follow-up) cost needed for saving the initial investment (Zeng, Zhang, Chen, Yu, & Gong, 2013). The former network includes regions involved in risk-assessment, such as the bilateral medial and superior frontal gyri. The latter includes regions involved in reward processing, including the caudate nucleus, and regions involved in conflict monitoring, such as the cingulate gyrus. Haller and Schwabe (2014) found that reduced activity in the ventromedial prefrontal cortex (vmPFC) and associated increased activity in the dorsolateral prefrontal cortex (dlPFC), presumably representing deficient integration of emotions into decision processes (Bechara, Damasio, Damasio, & Lee, 1999), is associated with a larger decision escalation bias. Fujino et al. (2016) found that the insula, inferior frontal gyrus (IFG), and anterior cingulate cortex (ACC) are activated during decision escalation; a similar network was found to encode gains and losses (Jessup & O'Doherty, 2014).

Together, these studies demonstrate that decision escalation can be mediated by activity in regions involved in risk aversion states, reward processing, integration of emotions and reflections, self-perception and conflict monitoring (Fujino et al., 2016; Haller & Schwabe, 2014; Zeng et al., 2013). They also show that different types of decision escalation (e.g., project-continuum paradigm vs. choosing between two alternative sunk costs, see Fujino et al., 2016), amounts of sunk cost and required follow-up investment (see Zeng et al., 2013) can produce different activation patterns involving different brain regions from the broader abovementioned network of regions. This alludes to the possibility that contextual factors may be also at play and can influence brain activations during decision escalation.

Here, we extend previous research on decision escalation in two directions. First, we demonstrate differences between brain networks that govern escalation (continue investing to try to save a failed investment) vs. de-escalation (accepting lost sunk-cost and cutting the losses) decisions from the gain-loss paradigm. Second, we account for the role of two contextual factors in affecting sunk cost bias: (1)

the framing of information regarding the potential outcome as success or failure of the follow-up investment (50% chance to succeed vs. 50% chance to fail), and (2) responsibility of the decision maker (whether the initial failed decision is made by the decision maker or others). In prior neuroimaging research on decision escalation, responsibility and framing were mostly constant. They can, however, vary between decision situations. It is therefore important to study their roles, and specifically how they affect the recruitment of brain regions for the escalation and de-escalation decisions.

Because decisions to escalate failed investments are driven by consonance restoration (i.e., trying to ensure that one's prior decisions, perceptions and future actions are consistent with one another), emotion processing and attempts to save one's self-image (Arkes & Blumer, 1985; Bazerman et al., 1984; Brockner, 1992; Sofis, Jarmolowicz, Hudnall, & Reed, 2015), it is reasonable to hypothesize that activity in the cingulate cortex, insula and precuneus will be higher in escalation decisions (H1). The cingulate cortex is involved in conflict monitoring, integration of monetary rewards with motor responses, and connecting emotion and memories (Botvinick, Cohen, & Carter, 2004; Bush, Luu, & Posner, 2000; van Veen & Carter, 2002; Williams, Bush, Rauch, Cosgrove, & Eskandar, 2004); the insula mediates interoceptive awareness processes and serves as a repository for negatively-valenced emotions and events (Chen, Li, Xu, & Liu, 2009; Craig, 2009; Flynn, Benson, & Ardila, 1999; Wright, Martis, McMullin, Shin, & Rauch, 2003); and the precuneus mediates self-perception processes (Cavanna & Trimble, 2006). All of these processes are expected to be activated when a person decides to risk further investment in order to avoid cognitive dissonance and restore his or her self-image. In contrast, when a person decides to cut his or her losses, we posit that decisions become more reflection- and inhibition-dependent. They are consequently likely to involve more momentary risk aversion and the mobilization of inhibition efforts. We therefore expect that in de-escalation decisions, regions involved in the inhibition of risky suboptimal choices and learning, namely the inferior and superior frontal gyri (Aron et al., 2003, 2004; Li, Wang, Wen, & Tan, 2018), will be relatively more active (H2)[1].

Given the central role of responsibility in motivating continued investment in failed projects (Arkes & Blumer, 1985; Bazerman et al., 1984), we expect that the abovementioned activations in escalation decisions (in the cingulate cortex, insula and precuneus) will be augmented when one's responsibility is higher compared to when it is lower (H3a). In other words, when one feels more responsible for the failed investment, stronger mental-self considerations are expected (Lou et al., 2004) and stronger mobilization of self-image and consonance restoration efforts will be needed. We also expect that when de-escalation decisions are made, low responsibility for past investment should further motivate momentary emphasis on risk aversion. Consequently, frontal gyri are expected to be more activated when the focus that one takes is more on risk aversion than on self- and social-image restoration. We hence anticipate that the expected increased activation in the inferior and superior frontal gyri in de-escalation decisions will be stronger under low responsibility compared to high reasonability conditions (H3b).

Lastly, the framing of potential outcomes can lead to more approach (avoidance) decisions when the provided information is positively (negatively) framed (Kahneman & Tversky, 1979). It is therefore reasonable to expect that the framing of the success probabilities of the follow-up investment can modulate the effects hypothesized in H1 and H2. We expect that when positive framing is used, a stronger tendency toward escalation decisions (“approach”) will form, and an increase in the associated activity in the regions described in H1 (ACC, insula, cingulate gyrus and precuneus) will be observed (H4a). Similarly, we expect that when negative framing is used, a stronger tendency toward de-escalation decisions (“avoidance”) will form, and an increase in the associated activity in the regions described in H2 (frontal gyri) will be observed (H4b).

[1] Both escalation and de-escalation decisions involve some internal conflict monitoring and processing, but we expect such conflicts to be more pronounced in escalation decisions (H1). The reason is that there is more at stake in such decisions (e.g., double the loss if the project fails after follow up investment) compared to when we accept the smaller loss through de-escalation. Hence, we do not assume significant cingulate cortex involvement in de-escalation decisions.

Results

Behavioral Results

For descriptive purposes, we observe that (1) the overall rate of escalation decisions and de-escalation decisions were 79.7% and 20.3%, respectively, and (2) the time for making escalation decisions (M=1.21, SD=.23) was significantly shorter (t=-3.59, p=.001) than that for de-escalation decisions (M=1.55, SD=.57). RM-ANOVA revealed that the main effect of framing on escalation decisions was significant (positive framing > negative framing; F=11.612, p=.002), while the main effect of responsibility was not (F=.319, p=.577). The interaction effect of these two factors was also significant (F=26.165, p=.000). Follow-up t-tests showed that high responsibility conditions increased escalation decisions only when they were positively framed; and positive framing increased escalation decisions only under high responsibility treatment. Unlike expected, high responsibility made it easier for participants to abort the project under negative framing condition. It was marginally significant. This may be because the messages framed negatively were more likely to make the subjects aware of risk, especially when the sense of responsibility was high. Tables 1 and 2 show the result of statistical testing.

Table 1 Results of RM-ANOVA for Escalation Decisions

Source	Escalation Decision		
	F Statistic	Sig.	Eta-squared
Responsibility	.319	.577	0.011
Framing	11.612	.002**	0.293
Responsibility ÍFraming	26.165	.000***	0.483

* p<.05. ** p<.01. *** p < .001.

Table 2 Results of paired- t Tests for Escalation Decisions

Condition		Escalation Decision			
		Mean	Std.	t	Sig.
High Resp.	Positive	.98	.03	6.212	.000***
	Negative	.64	.30		
Low Resp.	Positive	.74	.32	-1.211	.236
	Negative	.81	.27		
Positive Framing	High Resp.	.98	.03	3.972	.000***
	Low Resp.	.74	.32		
Negative Framing	High Resp.	.64	.30	-1.966	.059△
	Low Resp.	.81	.27		

△ p<.10. * p<.05. ** p<.01. *** p < .001.

FMRI Imaging Results

The objective of the analyses below was to address the following four hypotheses:

H1: that activity in the cingulate cortex, insula and precuneus is higher in escalation decisions.

H2: that the inferior and superior frontal gyri, are relatively more active in de-escalation decisions.

H3: that (a) the abovementioned activations in escalation decisions are augmented in high responsibility conditions, and (b) the abovementioned activations in de-escalation decisions are augmented in low responsibility conditions; and

H4: that (a) in positive framing conditions there is stronger activation in the ACC, insula, cingulate gyrus and precuneus; and (b) in negative framing conditions there is stronger activation in the frontal gyri.

A whole-brain analysis was conducted to find brain regions associated with escalation decisions and de-escalation decisions. It revealed that the right anterior cingulate cortex (ACC), right cingulate cortex, left insula, right medial frontal gyrus (MFG), and right precuneus were more active in escalation decisions (See Fig. 2, Panel A and Table 3), while bilateral inferior frontal gyrus (IFG), left medial frontal gyrus (MFG), and left superior frontal gyrus (SFG) were more active in de-escalation decisions (See Fig. 2, Panel B and Table 3). Therefore, hypotheses 1 and 2 were supported. Both escalation and de-escalation decisions usually involve using analytical processes or intuitive processes to solve the problems under uncertainty or ambiguous situations. Cingulate cortex and insula activated in escalation decisions involve emotional stimuli, while inferior frontal gyrus and superior frontal gyrus activated de-escalation involve cognitive stimuli. Obviously, de-escalation decisions are more likely to be related to rational processing than escalation decisions. The test result of response time also confirmed this. The decision time for de-escalation decision was greater than that for escalation decision, because rational processing usually need more time to elaborate information.

Table 3 Peak cluster activation for Escalation > De-Escalation and De-Escalation > Escalation contrasts

Brain Region	MNI coordinates			t-value	cluster size
	x	y	z		
Escalation > De-Escalation					
R. ACC	2	18	-2	3.94	54
R. Cingulate Gryus	12	-36	42	4.22	71
L. Insula	-54	-32	18	4.13	29
R. Medial Frontal Gyrus	14	-20	56	5.32	80
R. Precuneus	16	-54	58	4.69	81
De-Escalation > Escalation					
L. Inferior Frontal Gyrus	-36	18	-12	5.74	550
R. Inferior Frontal Gyrus	34	24	-10	5.26	199
L. Medial Frontal Gyrus	-6	20	48	6.16	255
L. Superior Frontal Gyrus	-4	32	50	4.77	285

To test hypotheses 3a-b and 4a-b, ROI data were extracted from [High Responsibility > Low Responsibility], [Low Responsibility > High Responsibility], [Positive Framing > Negative Framing], and [Negative Framing> Positive Framing] contrast maps. Results showed that there was no significant activation in ACC_R, Cingulate Gryus_R, Insula_L and Precuneus_R for [High Responsibility > Low

Responsibility], and only IFG_R activation was significant for [Low Responsibility > High Responsibility] contrast. Therefore, H3a was not supported, and H3b was partly supported. Positive framing strengthened the activations in ACC_R, cingulate gyrus_R, insula_L, and precuneus_R, and weakened IFG_L, IFG_R, and SFG_L activation. See detailed results in Tables 4 and 5.

Table 4 Results of ROI Analyses for Brain Regions Hypothesized to be involved in Escalation Decisions

Brain Regions Related to Escalation	High Responsibility > Low Responsibility			Positive Framing > Negative Framing		
	Contrast value	t	Sig.	Contrast value	t	Sig.
R. ACC	-.077	-.430	.665	.571	3.460	.001**
R. Cingulate Gyrus	-.451	-2.280	.985	.586	2.386	.012*
L. Insula	-.790	-3.251	.999	.961	2.797	.005**
R. Precuneus	-.267	-1.499	.927	.372	2.090	.023*

△ p<.10. * p<.05. ** p<.01. *** p < .001.

Table 5 Results of ROI Analyses for Brain Regions Hypothesized to be involved in De-Escalation Decisions

Brain Regions Related to De-Escalation	Low Responsibility > High Responsibility			Negative Framing > Positive Framing		
	Contrast value	t	Sig.	Contrast value	t	Sig.
L. IFG	.263	1.153	.129	.781	3.915	.000***
R. IFG	.328	1.857	.074△	.598	3.666	.001**
L. SFG	-.162	-.660	.742	.606	3.494	.001**

△ p<.10. * p<.05. ** p<.01. *** p < .001.

Because H3a-b was not fully supported, we further examined the interaction effect of responsibility and framing. Additional ROI data were extracted from [High Responsibility x Positive Framing > Low Responsibility x Positive Framing], [High Responsibility x Negative Framing> Low Responsibility x Negative Framing], [Low Responsibility x Positive Framing > High Responsibility x Positive Framing], and [Low Responsibility x Negative Framing > High Responsibility x Negative Framing] contrast maps. The results showed that there was no significant activation in brain regions hypothesized to be involved in escalation decisions, but activations of all brain regions hypothesized to be involved in de-escalation decisions (i.e. IFG_L, IFG_R, and SFG_L) were weakened by responsibility when messages were framed positively. See detailed results in Tables 6 and 7. Therefore, H3b was fully supported under the positive framing condition.

Table 6 Results of Post Hoc Analysis for High Self-Responsibility > Low Self-Responsibility in Brain Regions Hypothesized to be involved in Escalation Decisions

Brain Regions	Positive Framing			Negative Framing		
	Contrast value	t	Sig.	Contrast value	t	Sig.
R. ACC	-.001	-.012	.505	-.075	-.068	.750
R. Cingulate Gyrus	-.052	-.449	.672	-.398	-3.213	.998
L. Insula	-.253	-1.781	.957	-.536	-3.380	.999
R. Precuneus	-.051	-.564	.712	-.216	-1.758	.955

Table 7 Results of Post Hoc Analysis for Low Self-Responsibility > High Self-Responsibility in Brain Regions Hypothesized to be involved in De-Escalation Decisions

Brain Regions	Positive Framing			Negative Framing		
	Contrast value	t	Sig.	Contrast value	t	Sig.
L_IFG	.812	4.579	.000***	-548	-3.687	1
R_IFG	.652	4.736	.000***	-.323	-2.735	.995
L_SFG	.472	2.575	.008**	-.634	-4.670	1

We further performed mediation tests (see details in online supplementary file). They showed that the IFG mediated the effect of framing on escalation decisions under the responsibility and negative framing conditions; and that SFG activation mediated the effect of responsibility on escalation decisions under positive framing conditions.

Post-Hoc Mediation Analysis

Mediation models were conducted post-hoc to explore whether the brain activations associated with escalation and de-escalation mediated the relationship between responsibility/framing and escalation decision. As shown in table 1, there was an interaction effect between responsibility and framing on escalation decision. The mediating role of brain activations, then, was examined for each of three significant conditions in table 2. The mediation model included treatment (i.e. responsibility or framing) as the predictor, escalation decision as the dependant variable, brain activations from each of the four escalation ROIs and the two de-escalation ROIs as the mediator. Analyses were run using SPSS macro PROCESS with significance determined by 95% CI based on 1000 bootstrapped samples. The results showed that only the brain regions associated with de-escalation (i.e. IFG and SFG) play mediating role between responsibility/framing and escalation decision (as shown in figure 3). First, the IFG mediated the effect of framing on escalation decision under high responsibility condition. When the responsibility is high, the positive messages may reduce the activation of IFG, and then contributed to the subjects' escalation decision. This is why positive messages are more likely to lead to escalation decision than negative messages under high responsibility condition (As tested in table 2). In addition, the IFG also mediated the relationship between responsibility and escalation decision under negative framing condition. Responsibility is positively associated with IFG activation, and leads to prohibit the escalation behavior while receiving negative messages. This explains the marginally significant result in table 2. That is, high responsibility would contribute to de-escalation decision under negative framing condition. Finally, the SFG played a mediation role in the effect of responsibility on escalation decision under positive framing condition. When the subjects received positive messages, the higher responsibility was perceived, the lower SFG was activated, and further resulted in escalation decision. This finding illustrated that how responsibility affect escalation decision under positive framing condition.

Discussion

This study sought to shed light on (1) differences between the neural underpinnings of escalation and de-escalation decisions, and on (2) how these neural processes may be modulated by key contextual/confounding variables.

The first objective was addressed with H1 and H2. They were supported, but the implicated regions were largely lateralized. The results indicated that escalation decisions engage clusters in the right anterior cingulate gyrus, posterior parts of the cingulate gyrus, precuneus and medial frontal gyrus, as well as a cluster in the left insula. This activation pattern supports the assumption that escalation decisions require observing the conflict between the choices of accepting the loss and loss chasing (i.e., attempts to overcome past loses, through further or increased investing), and that they are motivated by self-image and interoceptive-awareness (Arkes & Blumer, 1985; Bazerman et al., 1984) as well as by cognitive consonance restoration (van Veen, Krug, Schooler, & Carter, 2009). In contrast, de-escalation decisions engaged clusters in the bilateral inferior frontal gyrus, and left superior and medial frontal gyri. This activation pattern supports the postulation that de-escalation requires stronger focus on momentary risk aversion and inhibition (Aron, Fletcher, Bullmore, Sahakian, & Robbins, 2003; Christopoulos, Tobler, Bossaerts, Dolan, & Schultz, 2009; Tops & Boksem, 2011).

The mediation models further contribute to the big picture by showing that while, as expected, different networks are activated in escalation and de-escalation decisions, the switch between such decisions is primarily dependent on inferior and superior frontal gyri regions, which mediate the integration of contextual information, such as framing and responsibility, into escalation vs. de-escalation decisions. This is in line with the functional role of frontal gyri regions in learning and decision making (Aron, Robbins, & Poldrack, 2004; Christopoulos et al., 2009).

Adding to this, the behavioral results showed that escalation decisions were made significantly faster compared to de-escalation decisions. This supports the assertion that while de-escalation decisions may be associated with more-reflective-analytical mode, escalation decisions are made in a more intuitive mode that focuses on peripheral (e.g., saving self-image) rather than central goals. This view extends extant neuroimaging works on decision escalation after an initial investment (Fujino et al., 2016; Haller & Schwabe, 2014; Zeng et al., 2013).

The second objective of the study was addressed with H3a-b and H4a-b. H3a proposed that activation of the cingulate cortex, insula and precuneus will be further increased in escalation decisions, when responsibility is high. H3b suggested that the increased activation of the inferior and superior frontal gyri in de-escalation decisions will be further increased when responsibility is low. Both parts of the hypothesis were not supported. A post-hoc analysis provided partial support for H3b by showing that it may hold true only under positive rather than negative framing conditions. This illuminates the need to account for confounding variables in decision escalation research. These results can be explained by the idea that positive framing created additional motivation to escalate the investment, and hence de-escalation when responsibility was low required additional neural risk aversion and inhibition efforts. These efforts are presumed to manifest in increased activation of the frontal gyri. Together, these findings suggest that responsibility, at least in the examined task, is not always confounded in escalation and de-escalation decisions; it becomes relevant only for de-escalation decisions when the success of the follow-up investment if positively framed.

H4a proposed that activation of the cingulate cortex, insula and precuneus will be further increased in escalation decisions, when the success probabilities of the follow-up investment are positively framed. H4b suggested that the increased activation of the inferior and superior frontal gyri in de-escalation decisions will be further augmented when the success probabilities of the follow-up investment are negatively framed. Both parts of the hypothesis were supported. This implies that framing is an important contextual extension of prior research on decision escalation (Fujino et al., 2016; Haller & Schwabe, 2014; Zeng et al., 2013). We show here that not only framing influences escalation and de-escalation decisions when facing sunk costs, but also expands the separation between the neural activations of brain networks involved in escalation versus de-escalation decisions.

Decision biases occur when objectively equivalent probability is presented as either positive framing or negative framing. As shown in table 2, negatively framed messages have a lower frequency of escalation biases than positively framed messages under high responsibility condition. In addition, the mediation model showed that negative framing increased IFG activation and further contributed to de-escalation decision. From a practical standpoint, our findings suggest that decision escalation bias can be alleviated by using more negatively framed success probabilities of follow-up investments, especially under high responsibility condition. For example, if a person wants to avoid exceeding his or her gambling limit, he or she should think about the probabilities of losing rather than winning the next bet. Similarly, managers should focus on project failure probabilities rather than on success probabilities in order to reduce the risk of being biased by sunk costs. The efficacy of such approaches, though, requires further research. The neural findings further shed light on the brain underpinnings of the shift from image saving to risk aversion focus. This suggests that people with deficits in the abovementioned brain networks may be more (or less) susceptible for decision escalation bias. While some evidence for such effects exists (e.g., it has been shown that gamblers differ from non-gamblers in their follow-up responses to wins and losses, see Brevers et al., 2017), future research should more closely examine how deficits in any of the brain regions examined here can affect escalation decisions. Future research may also examine the effects of therapies on sunk cost decisions of patients. For example, the ACC tends to be hyper-active in major depressive disorder and in bi-polar disorder subjects; and pharmacological and brain stimulation treatments can reduce ACC activity (Drevets, Savitz, & Trimble, 2008). The implications of such treatments for decision making in response to sunk costs are unknown, and should be examined.

Limitations

Several limitations of this study are noteworthy. First, the task had fixed success of follow-up investment probabilities, it belonged to the investment-continuum paradigm, and it did not vary the prior investment and follow up costs. Hence, the generalizability of our findings should be extended, by for example, replicating the study while using different decision scenarios, different success probabilities, and different levels of prior and needed investments. Second, the responsibility manipulation did not produce strong neural effects. Different tasks and manipulations may be developed in future research to better elicit such effects. Third, some potential confounding factors such as the forced choice in the experiment and project size (million dollars vs. billion dollars) can be accounted for in future research. Fourth, the decision was targeted at the decision stage and did not explore the complexity of multi-stage situations; this is a fruitful area for expansion. In addition, we focused on one biasing aspect of sunk cost, and did not delve into nuanced biases, such as the ability of sunk cost to drive violations of the stochastic dominance principle (Jessup, Assaad, & Wick, 2018). This also represents an important area for future research. Moreover, inferring vale assessment from brain imaging data is difficult (O'Doherty, 2014). Future studies can use additional experiments to more directly relate value judgments to sunk cost situations. Lastly, this study did not consider attributes of the decision makers, such as personality (especially agreeableness and conscientiousness, see Fujino et al. (2016)), experience and age of the subjects. Future research may extend our findings by integrating more covariates and predictors into the model.

Conclusions

Escalation of commitment to a failed project is a common decision bias. The goal of this study is to identify neural correlates associated with the escalation and de-escalation decision and the effect of responsibility and outcome framing. The findings showed that (1) escalation decisions are faster than de-escalation decisions, (2) the corresponding network of brain regions recruited for escalation (anterior cingulate cortex, insula and precuneus) decisions differs from this recruited for de-escalation decisions (inferior and superior frontal gyri), (3) the switch from escalation to de-escalation is primarily frontal gyri dependent, and (4) activation in the anterior cingulate cortex, insula and precuneus were further increased in escalation decisions, when the outcome probabilities of the follow-up investment were positively framed; and activation in the inferior and superior frontal gyri in de-escalation decisions were increased when the outcome probabilities were negatively framed. The findings contribute toward a better understanding of the mechanism underneath the decision escalation.

Methods

Study Design and Procedures

A 2x2 (responsibility x outcome framing) within-subject factorial design was employed. Responsibility was manipulated by presenting four software projects in which participants were asked to make an initial project decision regarding the development approach (High responsibility condition) and four other projects presented as having the development approach decided by others in the organization (Low responsibility condition), see Fig. 4 for a sample. In addition, the success or failure of the project would be related to the participants under high responsibility condition (decision scenarios presented as “If the project fails, it means you are incapable.”), but not related to the participants under low responsibility (decision scenarios presented as “If the project fails, it doesn’t mean you are incapable.”). Framing was manipulated by presenting decision scenarios with foci on either probabilities of success (Positive framing: “Increasing budget will have 50% chance of succeeding with the project") or probabilities of failure (Negative framing: “Increasing budget will have 50% chance of failing with the project"). The probability of success and failure was 50% .

Participants

Twenty-nine participants were recruited with the requirement that they need to have taken at least one Information Systems [IS] course in their college education, 13 females; age range 21-33, M_{age} = 23.6). All were healthy, right-handed, experiment naïve, and had normal or corrected-to-normal vision. They had no history of neurological or psychiatric disorders or contraindications to MRI. The experiment was approved by the Research Ethics Committee of National Taiwan University. All participants provided written informed consent and were paid about US$20 for their time.

Participants were asked to take the role of an Information System [IS] manager of a company, in which they are responsible for managing eight software projects that cost a lot of money and need more money to avoid failure. The original investment was sunk cost. It could not be recovered. For each project, they were given 14 decision scenarios in which the projects were in trouble. They had to decide whether to escalate (invest more to save the project) or de-escalate (stop the project).

MRI Procedure

Before the MRI scanning, participants were given 10 minutes for reading the descriptions of all eight project scenarios. Then, they were screened for physical and psychiatric disorders. No exclusions were made. Scanning commenced with structural acquisition for anatomic normalization (10 minutes). Functional scans were acquired from four sessions. In each session, two software projects were randomly assigned (one with high self-responsibility and another with low). Participants were given 20 seconds to review the description of each software project scenario. In the high self-responsibility condition they were asked to make an initial decision. Next, they performed 14 trials of project decisions in the different manipulated conditions. In each trial, participants were given a decision message for 6 seconds, followed by a decision response (continuing the project or not) for 4 seconds. For controlling the clicking movement, the ratio of “continue button” on the left side and the right side was counterbalanced. Each participant performed a total of 112 trials. The experimental paradigm is shown in Fig. 5.

Abbreviations

ACC : Anterior Cingulate Cortex

ACC_R: Right Anterior Cingulate Cortex

Cingulate Gryus_R: Right Cingulate Gryus

dlPFC: dorsolateral Prefrontal Cortex

fMRI: functional Magnetic Resonance Imaging

IFG : Inferior Frontal Gyrus

IFG_L: Left Inferior Frontal Gyrus

IFG_R: Right Inferior Frontal Gyrus

Insula_L: Left Insula

IS : Information Systems

M: Mean

MFG : edial Frontal Gyrus

MNI: Montreal imaging institute

MRI: Magnetic Resonance Imaging

Precuneus_R: Right Precuneus

Resp.: Responsibility

RM-ANOVA: Repeated Measures Analysis of Variance

ROI: Region of interest

SD: Standard Deviation

SFG : Superior Frontal Gyrus

SFG_L: Left Superior Frontal Gyrus

vmPFC: ventromedial PreFrontal Cortex

Declarations

Ethics approval and consent to participate: The fMRI experiment was approved by the Research Ethics Committee of National Taiwan University. Signed consent to participate information is available upon request.

Consent for publication: Consent for publication is available upon request.

Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interest: No conflict of interest.

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Author contributions: TPL, NSY, YWL, and SMH participated in problem definition, experiment design, data acquisition and analysis and OT involved in problem definition, data analysis and manuscript writing. All approved the final version of the manuscript.

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Figures

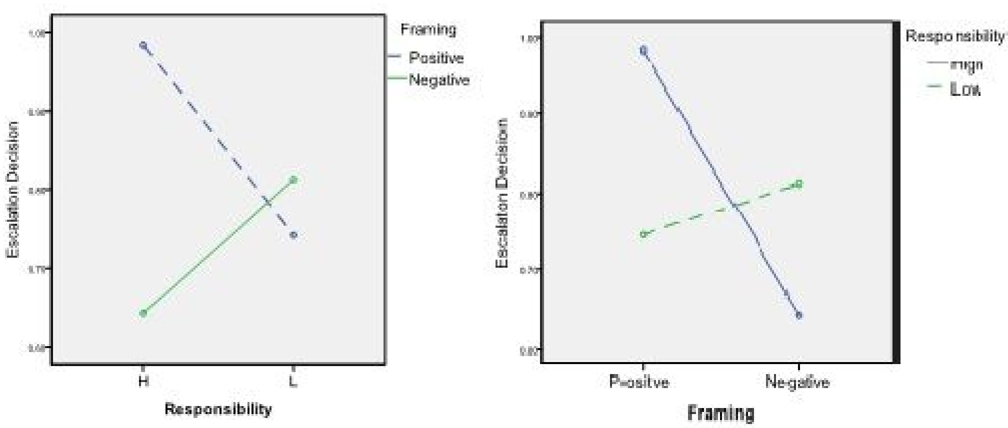

Figure 1

Graph of Interaction Effect of Responsibility and Framing on Escalation Decision

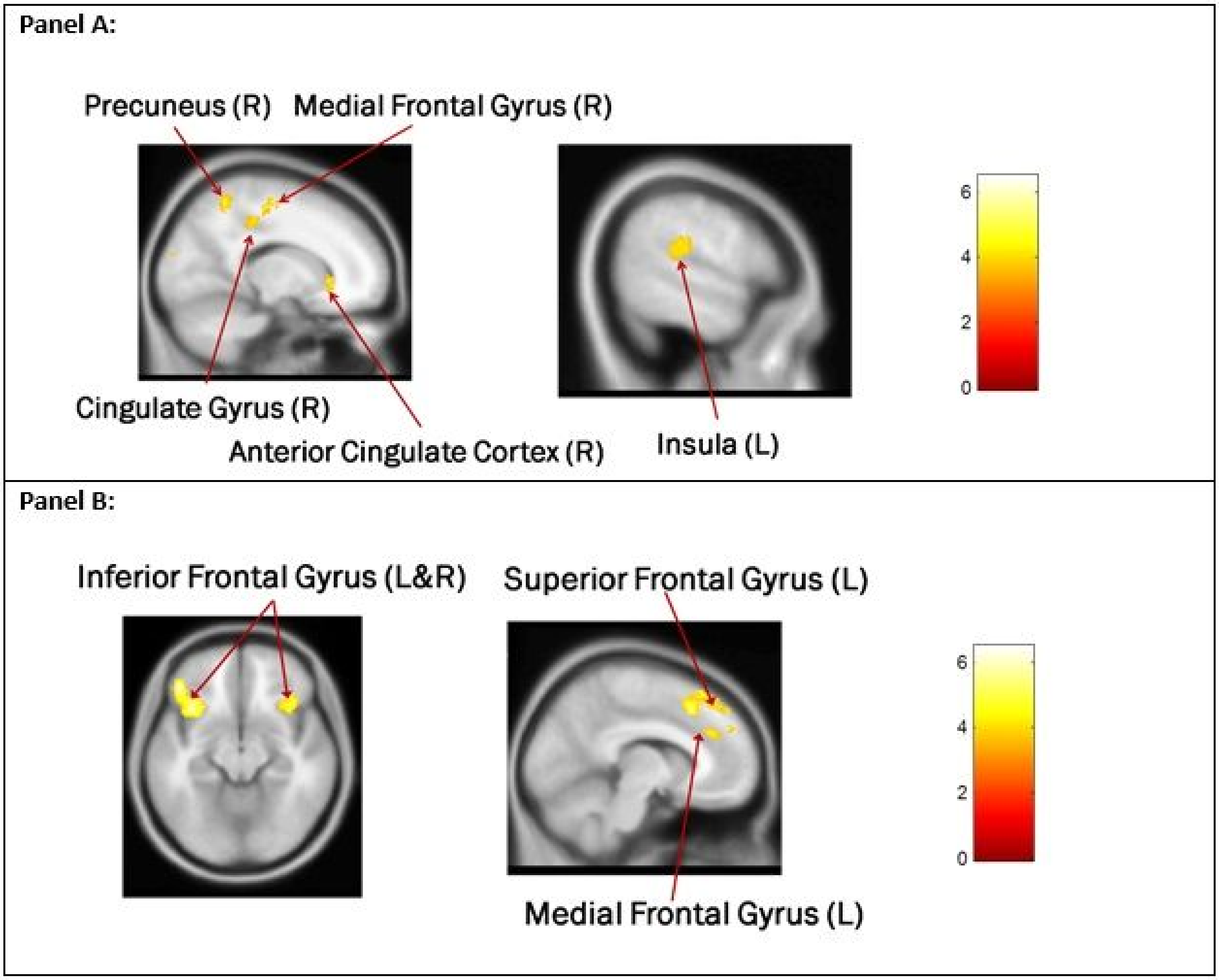

Figure 2

Panel A: Regions showing greater activation in escalation decisions than in de-escalation decisions [P < 0.001, corrected (False Discovery Rate), cluster size > 153, side-bar represents t-statistics]. Panel B: Regions showing greater activation in de-escalation decisions than in escalation decisions [P < 0.001, corrected (False Discovery Rate), cluster size > 212, side-bar represents t-statistics].

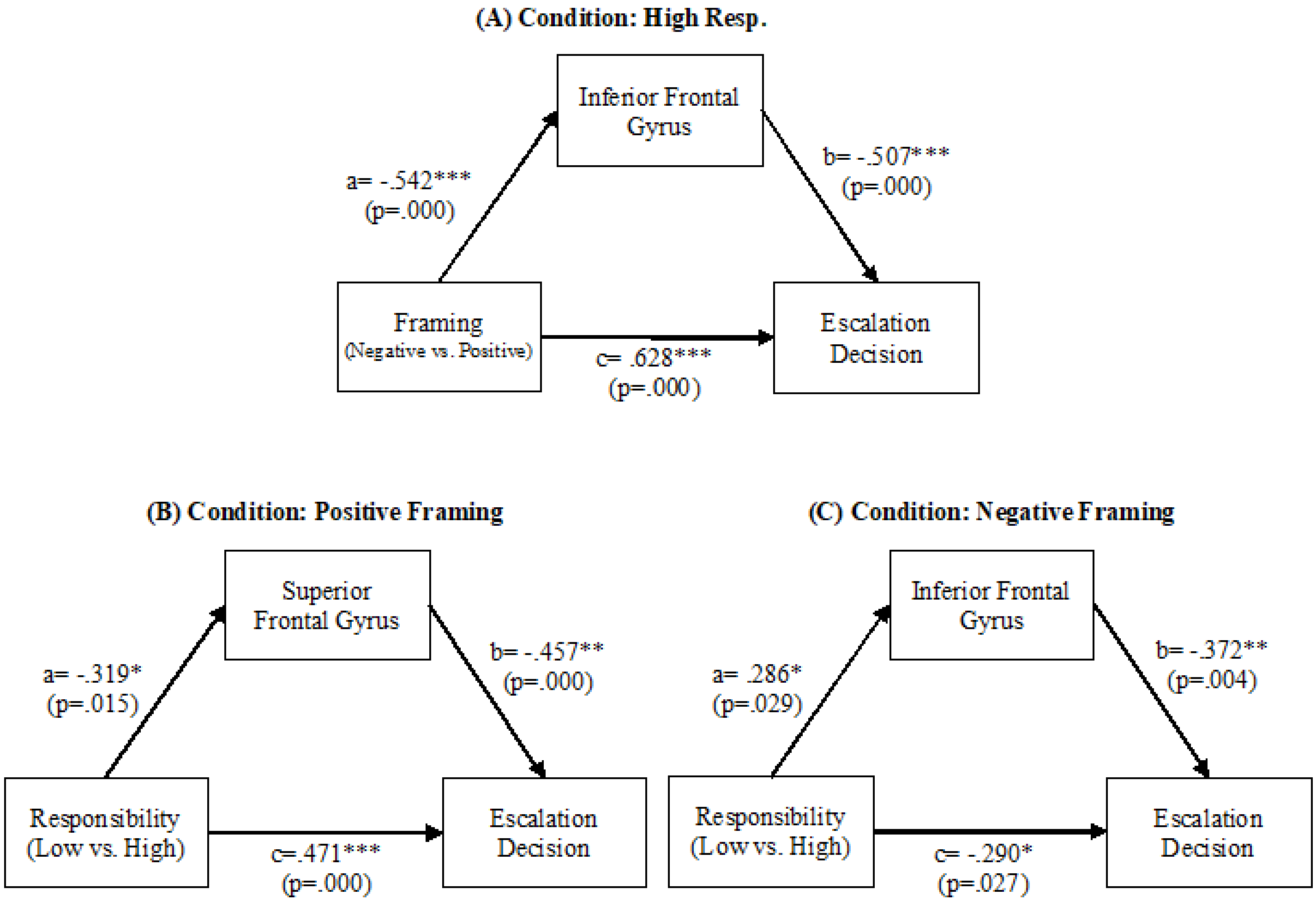

Figure 3

Mediation Model

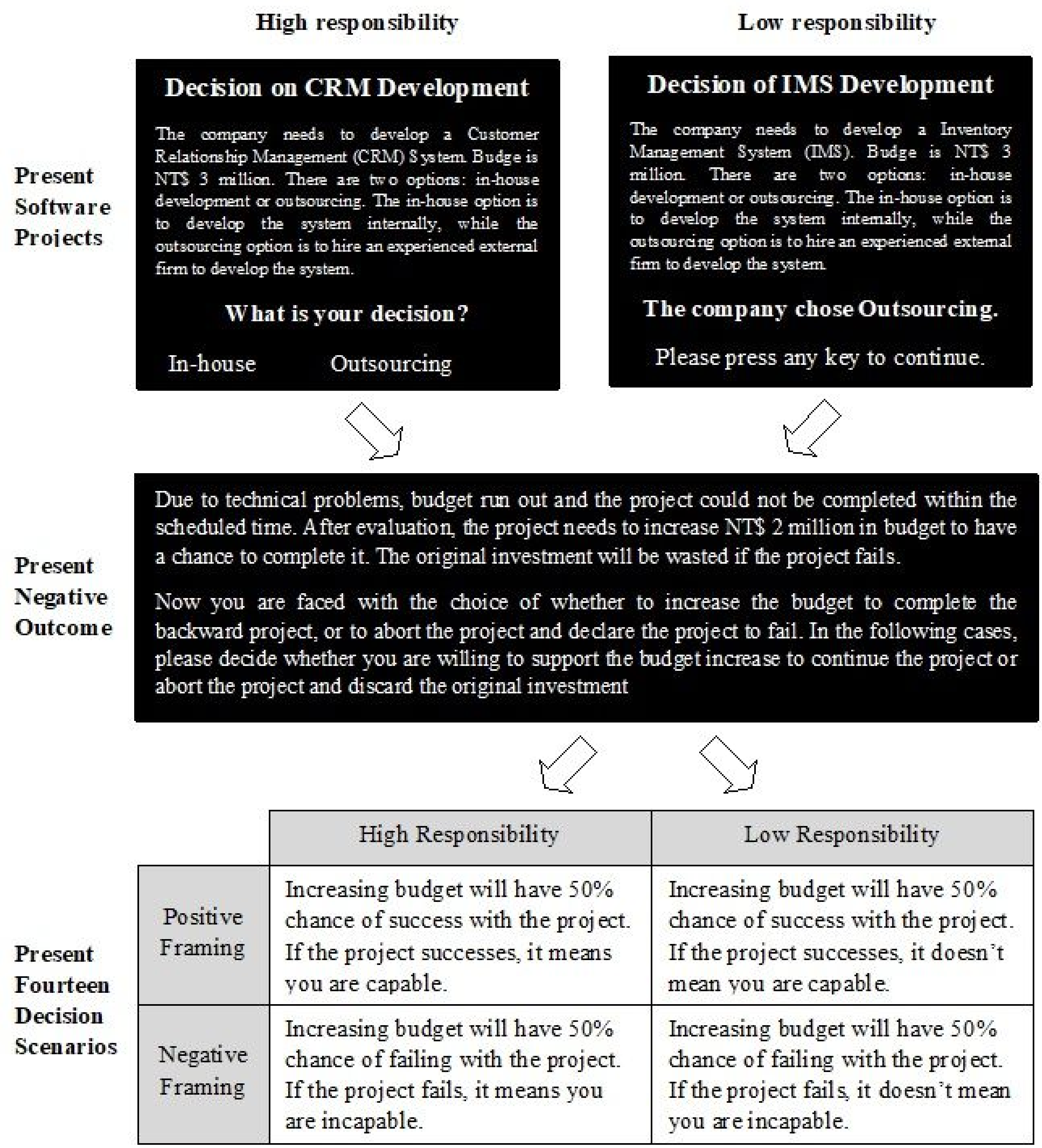

Figure 4

Procedure of the Experiment. Designated experimental scenarios were presented to subjects for their decision. High responsibility indicated asked the subject to commit to a choice, while the low responsibility indicated that the decision was done by others.

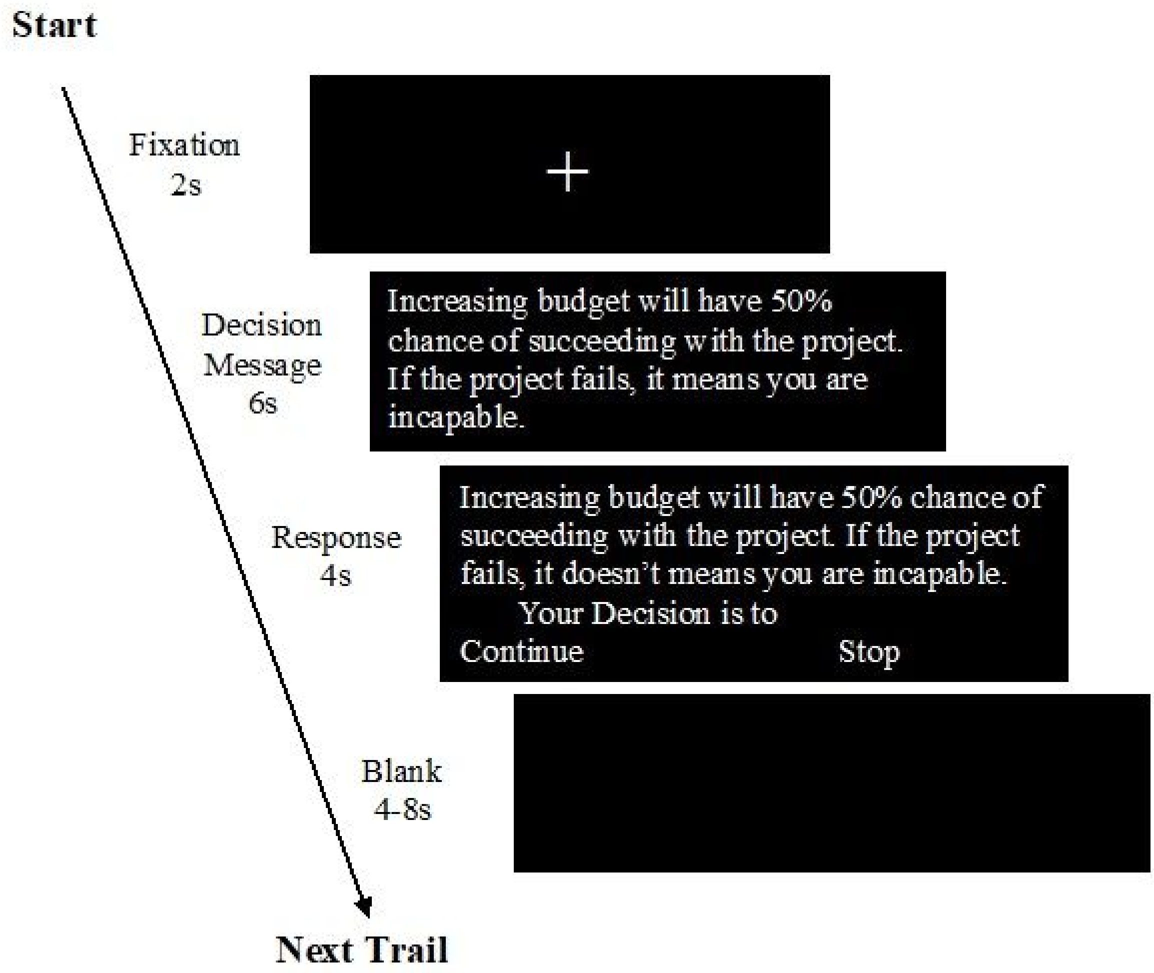

Figure 5

Experimental Paradigm. The problem for requesting an increase of financial commitment was presented to the subject and then ask for the subject to decide whether to stop the project. Image acquisition and statistical analyses are described in detail in the online supplementary file.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- DecisionEscalation5102020SupplmentalOnlineMaterial.pdf