COMENIUS UNIVERSITY IN BRATISLAVA

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EVALUATING AND EXPERIENCING FRAMED OUTCOMES:

FEEDBACK-RELATED NEGATIVITY INVESTIGATION OF DESCRIPTION AND AMBIGUITY EFFECTS

Master's thesis

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Supervisor:	Mag. Günther Greindl, PhD.
Consultant:	MS. Marijan Palmović, PhD.

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Abstract

Outcomes framed in terms of gains are usually considered more favorable than equal ones framed as losses. Differences in effects of framing on evaluations of certain and risky monetary deals were investigated in the present research. Additionally, event related potential (ERP) technique was used to examine analogy in evaluative processing between framed and objective gains and losses. Compared to gains, losses and ambiguity elicit a negative deflection in an ERP waveform, feedback-related negativity (FRN). Our experiment (N=17) consisted of 2 separate tasks. Participants first evaluated favorability of certain and risky outcomes. Following evaluations, outcomes were collected into final winnings in an EEG recording session task. All the outcomes resulted in objectively positive or neutral reward. Some outcomes, however, remained ambiguous and did not include information about the magnitude of the reward. No framing effect on evaluations of known outcomes was present. Responses to ambiguous outcomes, however, indicated significant framing effect. ERPs revealed no FRN differences related to gain and loss descriptions. On the other hand, ambiguity resulted in FRN independent from framing condition. Absence of framing effects in both FRN and evaluations between framed outcomes with known magnitudes could be indicative of outcome processing unbiased by description. The observed FRN associated with reward magnitude related ambiguity suggests an unexpectedly profound effect on outcome processing. Framing effect consistent responses to ambiguous outcomes dissociated from FRN suggest that other cognitive processes might be involved in behavior typical for framing effect.

Keywords: framing effect, attribute framing, ambiguity, feedback-related negativity

Abstrakt

Výsledky rámcované ako zisky sú zvyčajne posudzované priaznivejšie ako rovnaké výsledky, ktoré sú rámcované z poľadu strát. V našom výskume sme sa zaoberali rozdielmi vplyvu rámcovania na hodnotenia istých a riskantných peňažných ponúk. Technika vyvolaných potenciálov (event related potential - ERP) bola použitá na preskúmanie podobností medzi spracovávaním objektívnych a rámcových ziskov a strát. Straty a nejednoznačnosť, v porovnaní so ziskami, vyvolávajú zápornú výhylku v ERP krivke, negativitu spojenú s výsledkom (feedback-related negativity - FRN). Náš experiment (N=17) pozostával z 2 samostatných úloh. Participanti najprv posudzovali výhodnosť istých a riskantných ponúk. Výsledky týchto ponúk mohli potom zozbierať do finančnej výhry počas úlohy spojenej s EEG nahrávaním. Všetky výsledky ponúkali buď objektívne pozitívne alebo neutrálne odmeny. Niektoré výsledky, však, boli nejednoznačné a neobsahovali informáciu o veľkosti odmeny. Efekt rámcovania sa neprejavil v hodnoteniach výsledkov, ktorých veľkosť bola známa. Reakcie na nejednoznačné výsledky preukazovali významný vplyv rámcovania. Krivky ERP neodhalili žiadne rozdiely medzi rámcovanými ziskami a stratami v spracovávaní súvisiacom s FRN. Naproti tomu, nejednoznačné výsledky vyvolali FRN, ktorá bola nezávislá od rámcovania. Absencia vplyvu rámcovania na FRN a hodnotenia výsledkov so známou veľkosťou odmeny naznačuje spracovávanie neskreslené perspektívou opisu. FRN, ktorá bola prítomná pri výsledkoch s nejednoznačnou veľkosťou odmeny napovedá o neočakávane významnom vplyve na spracovávanie výsledkov. Disociácia rozdielov reakcií konzistentných s efektom rámcovania prítomných pri nejednoznačných výsledkov za súčasnej ekvivalencie FRN poukazuje na to, že kognitívne procesy nesúvisiace s FRN môžu vyvolať správanie typické pre efekt rámcovania.

Kľúčové slová: efekt rámcovania, rámcovanie atribútov, nejednoznačnosť, negativita spojená s výsledkom

Foreword

Framing effect was introduced into judgment and decision making research 35 years ago by "fathers" of cognitive biases, Tversky and Kahneman (1981). Extensive body of research addressed this phenomenon in the following decades. It took 17 years to introduce a widely recognized typology of risky choice, attribute and goal framing effects (Levin, Schneider, & Gaeth, 1998). Therefore, recent proposition by Kühberger and Gradl (2013), which came after another 15 years, that risky choice framing might be just a case of attribute framing was just too provocative to be left uninvestigated.

Combining behavioral experiment with physiological measures was motivated by both personal and research goals. Undertaking the research for my thesis was a challenge to broaden my methodological repertoire and to embrace the interdisciplinary nature of cognitive science. Exploring the neurophysiological basis was largely inspired by Ma et al. (2012) and was expected to clarify processual aspects of framing effect and contribute to relatively small body of research addressing this issue in the present topic.

I would not have embarked on this adventurous journey, if there was not for cooperation and assistance of my colleague Peter Kovár. I am most grateful to my supervisor Günther Greindl, who supported me in this enterprise and thanks to whom my interest in framing effect arose. The possibility to conduct my research at the Center for Postgraduate Studies, University of Zagreb made my work a rewarding experience, mainly thanks to Marijan Palmović, who guided me through preparation of the experiment. I am also thankful to the staff of the Center, mainly to Ana Branka Jerbić, for consulting me on various issues I encountered.

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Contents

Introduction

Framing effect is a well established phenomenon in judgment and decision making research. It refers to a wide range of changes in decisions or evaluations influenced by whether options or outcomes of actions are described positively or negatively. The aim of current research was to investigate risky choice task options within an attribute framing paradigm. This approach is inspired by recent experiments by Kühberger and Gradl (2013), who proposed that risky choice framing may be just a case of attribute framing. Furthermore, we attempted to verify whether the assumed description-representation coupling in framing tasks can be traced back to feedback-related negativity (FRN) which responses differently to gains and losses. Utilizing the characteristics of outcomes, introduced into our design from the framing effect paradigm, we investigated effects of ambiguity in various contexts on FRN.

1. Framing effect

Three distinct types of framing effects are most commonly addressed. Levin et al. (1998) introduced a typology that has remained profoundly influential, since it helped to alleviate prior confusion arising from variety of tasks being adapted by researchers. This typology distinguishes risky choice framing effect from attribute and goal framing effects. First, risky choice framing and the most commonly used tasks are introduced. Attribute framing description follows.

1.1. Risky choice framing effect

Framing effect was first described by Tversky and Kahneman (1981) in a range of tasks. Meta-analyses describe 10 basic task designs. The one which influenced subsequent research the most is the Asian disease problem. A meta-analysis based on experiments published before 1997 showed that 80 out of 230 experiments used this problem as a template for their materials (Kühberger, 1998). A newer meta-analytic review surveying articles published between 1997 and 2003 revealed similar results; 71 out of 151 designs were based on the Asian disease task (Gambara & Piñon, 2005).

Original formulation of the problem with observed proportions of choices between options described in parenthesis (Tversky & Kahneman, 1981, p. 453):

> *Imagine that the U.S. is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Which of the two programs would you favor?*
>
> ***Frame of gains***
>
> - *If Program A is adopted, 200 people will be saved. (72%)*
> - *If Program B is adopted, there is 1/3 probability that 600 people will be saved and 2/3 probability that no people will be saved. (28%)*
>
> ***Frame of losses***
>
> - *If Program C is adopted, 400 people will die. (22%)*
> - *If Program D is adopted, there is 1/3 probability that nobody will die and 2/3 probability that 600 people will die. (78%)*

The commonly observed pattern of choices is preference for the certain Program A in frame of gains and preference for risky Program D in frame of losses. The reason why this difference in preferences has been attracting researchers' attention is that Program A is formally equivalent to Program C (gains: *600 expected to die & 200 will be saved => 400 will not be saved*), merely described differently. The same applies to the pair of programs B and D. Furthermore, from the normative perspective, they are all equal in their expected values, since *1 probability x 200 lives saved= 1/3 probability x 600 lives saved*. Therefore, a rational decision maker should have no reason to prefer one option to another and the distribution of choices in such tasks should result in no obvious preference of any of the programs in a population. However, ample evidence shows a large effect of descriptions on choices in Asian disease-like tasks (Gambara & Piñon, 2005; Kühberger, 1998).

Other commonly used tasks in risky choice framing effect experiments are gambles. Meta-analytical data shows that gambling tasks were earlier used in 32 out of 230 (Kühberger, 1998), later in 7 out of 151 (Gambara & Piñon, 2005) experiments. They are generally variations on a combination of problems 11 and 12 used by Kahneman and Tversky (1979). A slightly modified gambling task from Kahneman and Tversky (1979, p. 273) with observed distribution of choices indicative of framing effect in parenthesis:

Frame of gains

In addition to whatever you own, you have been given 1,000. Now you are asked to choose between:

- *A: 50% chance to gain 1,000 (16%)*
- *B: 100% chance to gain 500 (84%)*

Frame of losses

In addition to whatever you own, you have been given 2,000. Now you are asked to choose between:

- *C: 50% chance to lose 1,000 (69%)*
- *D: 100% chance to lose 500 (31%)*

Here, again, the expected values between options are equal. All the options have expected value 1,500, which deems this shift of preferences irrational, being a violation of description invariance (Tversky & Kahneman, 1981). Framing effect manifests as risk-aversion in frames of gain and risk-seeking choices in frames of losses, despite that the objective outcomes are equal in both conditions.

Gambling tasks and Asian disease-like problems are usually treated as the same problem, with the distinction of gambles being in the domain of money and Asian disease in the domain of human life (e.g. Fagley & Miller, 1997). However, we suggest, an important difference if often being overlooked. Gambling tasks ordinarily involve positive initial endowment, while Asian disease problems are based on initial loss. Furthermore, the initial endowment in gambles often varies between frames, since it is essentially used to manipulate the frame (e.g. LeBoeuf & Shafir, 2003; Stanovich & West, 1998; Thomas & Millar, 2012; Tversky & Kahneman, 1981). We believe that manipulating initial endowment between frames makes it difficult to distinguish framing effect from endowment effects.

A novel simple gambling task was introduced into framing effect research by De Martino et al. (2006), in which this limitation was overcome. Instead of offering participants additional money to the initial endowment, the options were phrased in terms of how much of the endowment is being kept or lost, thus increasing resemblance to the Asian disease problem. The risky option consisted of two possible outcomes: "keep all" and "lose all", with varying degrees of probability. This task was later adapted in other experiments as well (Zeng et al., 2013). However, we argue that the risky alternative formulation is not optimal, since it introduces a risky option with a mixed frame. In our research we try to address this issue with a slight modification.

1.1.1. Prospect theory account

The most widespread theoretical background used in investigations of risky choice framing effect is the prospect theory (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992). Indeed, more than 100 out of 130 empirical papers use prospect

theory as an explanatory framework (Kühberger, 1997). The fundamental concepts of prospect theory are reference point and value function[1].

Reference point can be in the simplest case the status quo – state of affairs or current wealth, to which changes are referenced. However, factors such as expectations, aspirations, and for our current investigation most importantly, descriptions have an impact as well (Kahneman & Tversky, 1979). The reference point is determined in an early coding decision making phase (Kahneman & Tversky, 1979). In this phase, potential outcomes are put into relation with a reference point. Anything better than the reference point is evaluated as gain, while any states that are worse, are evaluated as losses during the subsequent processing. The prospect theory account of framing effect suggests, that describing outcomes as gains promotes adapting gaining nothing as a neutral reference point and loss descriptions induce losing nothing as a reference point (Kühberger, 1997). Preference reversals are then a result of subsequent evaluation of these gains or losses.

The value function describes how outcomes are subjectively evaluated. This S-shaped function is rather omnipresent in behavioral decision making literature. The shape of the value function is concave in the domain of gains, reflecting diminishing sensitivity. In the domain of losses, the value function is steeper and convex. Overall decision utility of an outcome is a product of a subjective value derived from the value function and probability of the outcome.

Taking the gamble described above as an example, the prospect theory explanation would follow this logic (explanation adapted from Kühberger, 1997, p.131). In the frame of gains, "keeping 0" would be adapted as a reference point. Option A will be evaluated as *50% probability x 1,000* and option B as *100% probability x 500*. Since the utility

[1] Prospect theory describes a non-linear weighting function for assessing subjective evaluation of probability; however, we will omit this function for reasons of simplicity. The shape of value function is sufficient for prospect theory account of framing effect.

function is concave in the domain of gains, keeping 500 is more than ½ as good as keeping 1 000. Therefore, the certain option B is preferred in frame of gains. This gamble in the domain of losses should elicit an adaptation of "losing 0" as a neutral reference point. The option C would be evaluated as *50% probability x -1,000* and option D as *100% probability x -500.* Convex value function in the domain of losses implies that losing 500 is more than ½ worse than losing 1,000, which makes the risky option more preferable.

1.2. Attribute framing

The above mentioned Asian disease problem and gambles are most commonly examined in tasks, where participants are faced with a choice between two options within a single frame. Recent experiments have demonstrated that framing might impact certain and risky options differently in an Asian disease problem (Kühberger & Gradl, 2013).

Attribute framing experiments usually compare evaluations of objects or situations from positive and negative perspective. Relating this directly to gambling problems, which are investigated in present research, a certain option can be described as the amount of money kept or lost. The risky option, on the other hand, can be described as a probability of losing or a probability of keeping money. Framing effect in these tasks is manifested as valence consistent shift of evaluation; positively described items are evaluated more favorably as the negatively described ones.

Kühberger and Gradl (2013) proposed, that observed patterns of choice reversals in risky choice framing may result from framing effect on evaluation of a single or both alternatives available in a decision, or be grounded in the process of the option comparison, independent from evaluation. In a series of between-subject experiments, they presented participants with the Asian disease problem as a choice task and an evaluation task as well. Analyses of evaluations of risky and certain options showed

different patterns. While evaluations of certain options were more favorable in a frame of gains then losses, the effect of framing on risky option was minimal to non-existent (Kühberger & Gradl, 2013). Furthermore, ratings of options were quite consistent with participants' choices between the two options. These results suggest that risky choice framing might be merely a byproduct of attribute framing, rather than a separate class of framing effects.

Explanation based on associative nature of memory is most commonly used to interpret attribute framing effect. Describing an object or an event from a positive perspective makes the positive aspect more salient, which influences encoding and processing (Levin et al., 1998). It is proposed that these positive associations lead to more favorable evaluations of given stimulus as compared to negative associations in a negative frame.

1.3. Affect and cognitive effort

Evidence indicating influence of affect shows that induction of positive emotions reduces framing effect (Cassotti et al., 2012). It has been proposed that affect drives risky choice framing effect, through modulating the amount of cognitive effort exerted in solving the problem (Gonzalez, Dana, Koshino, & Just, 2005; Kahneman & Frederick, 2007). Negative affect elicited by negative framing is assumed to increase the willingness to exert cognitive effort by perceived unpleasantness of outcomes (Gonzalez et al., 2005). An eye-tracking study showed that negative frame prolonged fixation duration and processing time on words in risky choice descriptions (Kuo, Hsu, & Day, 2009). These studies, however, investigated cognitive effort in risky choice framing tasks. Nevertheless, we propose that the same effect might apply to attribute framing. If we assume that risky choice framing is a result of attribute framing, we can hypothesize that affect has influence on the evaluative process. Indeed, a difference in cognitive effort has been observed in attribute framing task, as well (Kuvaas & Selart, 2004). Positive emotions should be eliciting an impression that the option is good, while

negative affects indicate a problem that might be threatening or unpleasant, therefore more cognitive effort and deliberation is dedicated to evaluation or choice (Kuvaas & Selart, 2004).

Affective account of framing effects is compatible with associative explanation proposed by Levin et al. (1998). Negative associations related to outcomes framed as losses might contribute to elicitation of unpleasant emotions. The effect of positive emotions could induce the impression of liking, while negative ones result in dislike. This notion is extended by a proposition that dislike elicits higher willingness to exert cognitive effort.

1.4. Description and processing

Prospect theory expects that description of a problem in terms of losses or gains implies evaluations of the options as gains or losses. Associative memory account, again, assumes that describing an object or an event to participants in a positive or a negative way leads them to represent or process it in the description-consistent manner. For all these explanations to hold, internal representations and processing should be consistent with the intended description manipulation.

The assumption that problem description necessarily causes internal representation of the outcomes as gains or losses has been questioned (Maule & Villejoubert, 2007). Several attempts to investigate how framed decisions are being processed have been made. Maule (as cited in Maule & Villejoubert, 2007) used verbal protocols for this purpose. Participants were thinking aloud, while solving the Asian disease problem. Those participants, who were only mentioning lives saved, were risk averse, opting for the certain option. Others, who were considering losses, had risk seeking preferences. These observations are consistent with patterns predicted in framing effect. However, participants who mentioned both lives saved and lost showed no preference reversals.

We propose that EEG measurements could be used to shed some light into the debate. Objective gains were shown to be distinguishable from objective losses in number of ERP studies, which are reviewed in the section 1.5.1. To investigate effects of framing on outcome valence processing as gains or losses, we will identify, whether the distinction of ERP waveforms for objective gains and losses applies to framed ones as well.

1.5. Framing in the brain

Despite the prospect theory being a formal descriptive model, based mainly on behavioral results, it makes statements regarding processing of decisions. It is therefore not surprising that it attracted attention of cognitive researchers. Treppel et al. (2005) reviewed neuroscientific evidence in an attempt to outline roles of different brain regions possibly linked to decisions under risk. Structures presumably associated with value function, contributing to evaluation of utility, listed in this review are striatum, amygdala, ventromedial prefrontal cortex (VMPFC) and anterior cingulate cortex (ACC).

Neuroimaging fMRI studies revealed differences in blood-oxygen-level dependent (BOLD) responses in risky choice framing effect tasks in multiple regions. Increased responses in amygdala have been observed in framing effect consistent choices, while increased activation of ACC seemed to be related to reversed pattern of preferences (De Martino et al., 2006). Furthermore, increased activity in orbital medial prefrontal cortex (OMPFC) and VMPFC seemed to be correlated with individual susceptibility to framing effect. Similar results relating activation in VMPFC to resistance to framing effects were observed by Deppe et al. (2005). These findings of neural correlates of susceptibility to framing effects were also reacted upon by Kahneman and Frederick (2007), who interpreted this activation pattern in OMPFC as a possible locus of inhibition of fast and intuitive responses.

This development in risky choice framing effect, brought by imaging studies has encouraged a more cognitive perspective to be taken in related research. Recent behavioral evidence of possibly differential impact of framing on risky and certain options (Kühberger & Gradl, 2013), however, has led our present research to take a step back from risky choice framing to attribute framing, which should be a cognitively simpler effect.

Currently, only one neurophysiological article related to attribute framing has been published in English[2]. Ma et al. (2012) investigated evaluations of certain options from Asian disease problem in an ERP study. In their experiment, participants were first presented with information about how many people were expected to die from a disease, if no action is taken. Afterwards, they were presented with an outcome feedback of how many people were saved or how many people died. Participants could evaluate this outcome as good or bad. Outcomes described in terms of people dying or being saved, overall resulted in the same amount of casualties. Nevertheless, behavioral results indicated that positively described outcomes were evaluated more favorably than the negative ones, which is consistent with framing effect. ERP waveforms showed a significant difference in an amplitude of feedback related negativity (FRN) between the two conditions. Processing an outcome described as number of people dying elicited larger FRN as compared to positively framed outcomes. These results indicate that irrespective of the objective outcomes, considering that some people always died, positively described outcomes tend to be processed as gains, while negatively described ones as losses.

FRN could therefore be a promising indicator, allowing valence processing measurements and possibly clarify the question of how framing is related to this processing. Together with the suggestion that risky choice framing might be just a case

[2] One additional article might be relevant, however, it was published in Chinese: Zhang, F., Zeng, J., & Zhang, Q. (2010). Framing effect: Affective heuristics. Psychological Science (in China), 33, 1375-1380.

of attribute framing (Kühberger & Gradl, 2013), FRN as a tool might prove to be very useful in future experiments.

1.5.1. Feedback related negativity

Feedback related negativity is an ERP component distributed in frontomedial scalp areas reaching its maximum amplitude about 250 ms after presentation of feedback (e.g. Holroyd, Larsen, & Cohen, 2004). Since this component was originally assumed only to be a sign of errors in responses, it is also referred to as error-related negativity (ERN or Ne). Gehring and Willoughby (2002), however, demonstrated that negative deflection superimposed on P3 component is not exclusive for ERPs following an erroneous response, labeling the component as medial-frontal negativity (MFN). The negative component also reflects distinction between domains of gains and losses. Similarity in scalp distributions of the potentials and their latency soon led to a controversy about possible common underlying neurophysiological processes involved in generation of these two components (Holroyd, Coles, & Nieuwenhuis, 2002). However, subsequent experiment addressing the error and gain/loss feedback dissociation provides more evidence to the point, that these two components might, indeed, be results of the same cognitive processes (Nieuwenhuis, Yeung, Holroyd, Schurger, & Cohen, 2004). In the present research, we will be referring to this component as feedback-related negativity (FRN).

FRN is thought to be a measure of motivational and affective impact of outcomes (eg. Gehring & Willoughby, 2002; Masaki, Takeuchi, Gehring, Takasawa, & Yamazaki, 2006). The likely source of FRN is assumed to be in or in proximity to ACC (Gehring & Willoughby, 2002; Yu, Zhou, & Zhou, 2011). ACC has been implied in both affective and cognitive processing (Bush, Luu, & Posner, 2000). FRN is most usually interpreted within reinforcement learning framework, claiming that it reflects arrival of dopamine reward signal from midbrain structures to ACC (Gehring & Willoughby, 2002; Nieuwenhuis et al., 2004; Yeung, Holroyd, & Cohen, 2005). However, other sources including striatum, posterior cingulate or right frontal gyrus have been proposed (Foti,

Weinberg, Dien, & Hajcak, 2011; Nieuwenhuis, Slagter, von Geusau, Heslenfeld, & Holroyd, 2005).

Despite some inconsistency in evidence related to generation of FRN, it has been shown to reliably differentiate between positive and negative outcomes. Our investigation addresses the issue, whether framing has a similar effect on FRN as objective valence of outcomes. We selectively reviewed FRN experiments using stimuli indicating gains and losses to identify how framing manipulation might affect ERP patterns.

1.5.1.1. Gains and losses

Differences in FRN after receiving a feedback conveying an information about monetary gains and losses were first reported by Gerhring and Willoughby (2002). In their experiment participants had a choice between a higher and a lower value. Following the choice, they received a feedback whether given amount of money was won or lost. Significantly larger amplitude of negative deflection with onset at around 150 ms after receiving feedback information was observed when participants lost money as compared to trials, where they won. It was proposed that FRN reflects a rapid evaluation of gains and losses. A number of subsequent experiments confirmed dependence of FRN amplitude on the outcome feedback valence.

FRN was shown to be independent from reward magnitude (Hajcak, Moser, Holroyd, & Simons, 2006). Valence and magnitude seem to be aspects of outcome evaluation processed by separate systems. Valence of an outcome is reflected in FRN amplitude, while the magnitude affects the subsequent P3 component, irrespective of valence (Yeung & Sanfey, 2004). Further investigation of reward magnitude modulating effects on FRN confirmed no relation between FRN amplitudes and magnitudes of monetary gains or losses (Hajcak et al., 2006). Current results suggest that FRN should reflect a binary evaluation of outcomes as gains or losses, good or bad ones (Hajcak et al., 2006).

Interestingly, this component is not necessarily associated with outcomes that result from individual actions. In the previously described experiments, the feedback which participants received was somehow contingent on their choices. Participants made a choice and then learned its outcome. However, FRN amplitude differences between monetary gains and losses have been demonstrated in experimental tasks, where participants did not make any choices and even when they executed no behavioral action and merely attended to outcomes presented on a screen (Yeung et al., 2005). FRN amplitudes observed in absence of a choice or an action were smaller in comparison with choice tasks. Effects of task on the FRN amplitude decrease, nevertheless, seemed to be attributable to subjective involvement in the given task, which could have been related to affective and motivational impact of the stimuli.

1.5.1.2. Neutral outcomes

Effects of neutral outcomes on FRN were first investigated in a series of 5 experiments by Holroyd et al. (2006). One of them, however, used "neutral" outcome as uninformative and is described in the following section 1.5.1.3., where it is treated as an ambiguous outcome. In gambling tasks with variety of contexts, it was shown that neutral stimuli ("0") elicited FRN responses similar to losses, when alternative outcomes were losses and gains. The same pattern was observed by Gu, Ge, et al. (2010).

Responses to neutrality seem to be dependent on the context. The aforementioned experiments included both gain and loss conditions, along with a neutral one. In a series of experiments, where context of neutrality was manipulated, FRN was associated with neutral outcomes when other experienced outcomes consisted of gains only, however, not when all the other outcomes were losses (Holroyd et al., 2004). This observation suggests some degree of reference-dependence of FRN responses to outcomes. Neutral outcomes seem to produce FRN only in a context of either gains and losses or gains.

1.5.1.3. Ambiguity

Holroyd et al. (2006) included "uninformative" outcome feedback in Experiment 2. After making a choice, participants received either a positive monetary reward or lost some money. Additionally, one condition consisted of stimuli, which meant that they either won or lost; it conveyed no useful information about the real outcome. The results not only confirmed that FRN amplitudes for gains were more negative as compared to losses, but also showed that the FRN was larger for uninformative stimuli as well. Furthermore, there was no difference between negative, neutral and uninformative outcomes. Following experiments adapted this framework to investigate differences in FRN responses between groups with varying levels of anxiety or neuroticism; however, for reasons of simplicity, only more general results will be reported here.

In another experiment, participants performed a time estimation task with monetary rewards for good performance (Hirsh & Inzlicht, 2008). Feedback stimulus indicated whether they were successful in estimating 1 second interval or not. In some trials, however, they did not receive informative feedback about their performance. FRN was, again, observed for feedback stimuli indicating failure and not success, which results in monetary reward. Ambiguous stimuli produced similar FRN response to the one associated with failure to correctly estimate 1 second interval.

Two more experiments conducted by one team of researchers investigated ambiguity in a simple gambling task (Gu, Ge, et al., 2010; Gu, Huang, & Luo, 2010). Participants first chose a small or a big gamble. Subsequently, they received feedback whether they won or lost given gamble. In some of these gambles, participants again, did not learn the outcome, which means that they could have lost or gained. Both experiments confirmed significant FRN associated with ambiguous outcomes. Consistently with previous research, no difference between negative and ambiguous outcomes was found. Furthermore, when neutral condition was present, the FRN responses between neutral and ambiguous outcomes were equal (Gu et al., 2010).

1.6. Present research and hypotheses

Evidence suggests that framing affects how people evaluate and decide. Both prospect theory and valence-based associative memory explanation assume that the way outcomes are described influences how they are being processed. An intriguing experiment investigating ERPs related to processing of framed outcomes came up with a proposal that the framing effect might influence very early stages of information processing reflected in FRN (Ma et al., 2012). The main goal of present experiment was to further investigate this possibility and examine FRN during processing of framed outcomes.

Despite attempts to bridge low level cognitive processing with judgment and decision making (e.g. Rangel, Camerer, & Montague, 2008; Trepel et al., 2005), no comprehensive account of framing effect has been developed so far. Various indices and emerging imaging studies are starting to outline the structures involved in framing effect. Nevertheless, theoretical model that could account for shifts in preferences, differences in cognitive effort and the role of FRN in this complex is currently out of reach. Therefore, present research might be somehow theoretically confined, but potent at the same time. Possibility that risky choice framing could be traced within attribute framing is attractive, since it is a simpler case of effect, because only one outcome is evaluated at a time. In risky choice framing tasks, at least two possible outcomes are assessed simultaneously. Establishing that low level processing indexed by FRN is related to outcome description manipulation would be useful in determining the processual differences in the gain/loss dimension. Furthermore, finer research in individual susceptibility to framing effect and its dependence on this component might ensue. Exploration of this outlook is a central aim of the present research.

Gambles used in risky choice framing research usually consist of an initial endowment and 2 options – risky and certain. Risky option offers a probability of keeping the entire endowment and a complementary probability of keeping nothing, when framed in terms of gains. Negatively framed risky option describes a probability of

losing the whole initial endowment and, again, a complement of losing nothing. Certain option offers only one possible outcome, which has an equal expected value as the risky one. It informs about how much of the initial endowment is kept or lost, depending on the frame. However, at least some part of the endowment is always kept. These two types of options can be classified as "all or nothing" and "always something" deals. In the remainder of this work, we will be using labels "risky" or "all or nothing" deals and "certain" or "always something" deals as synonyms. This distinction is a fundamental characteristic of our experimental design.

Framing effects are investigated separately for "always something" and "all or nothing" deals. Two approaches are combined. Effects of framing on favorability evaluations are addressed behaviorally from a perspective of attribute framing paradigm. The second approach of the present research is aimed to clarify the processual attributes of experiencing framed outcomes, using FRN as a measure of gain and loss processing. Framework by Ma et al. (2012) was adapted for a gambling task and extended to investigate processing of "all or nothing" outcomes. For this purpose, outcome descriptions inherent to framing effect were combined with results of FRN experiments examining ERP responses to neutral outcomes. Furthermore, uncertainty underlying "all or nothing" deals is explored in a context of ambiguity, in an attempt to bring insight both to understanding processes involved in framing effect and FRN responses to ambiguous stimuli.

Our predictions can be divided into 3 main areas. First, we investigated attribute framing effects on evaluations of certain and risky deals. FRN was examined to assess effect of framing on valence processing. The third area of the present research is explorative in nature and utilizes properties of framing in outcome presentation to extend existing body of research on FRN in neutral and ambiguous outcomes.

Following the experiments of Kühberger and Gradl (2013), we expected to observe framing effects in evaluations of certain deals and no significant framing effects in the

risky deals. Certain deals were predicted to be evaluated as more favorable in a frame of gains than in frame of losses. This difference should not occur in the risky deals.

Negative framing should increase the willingness to exert more cognitive effort (Gonzalez et al., 2005; Kuo et al., 2009). We expected the effort asymmetry to manifest in differences in reaction times. Longer reaction times were predicted to be associated with negatively framed deals as compared to positively framed ones.

Based on previous results of Ma et al. (2012), we expected outcomes framed as losses to elicit FRN, as compared to gain framed outcomes. Comparing the FRN between frames should help us verify differential processing of framed outcomes as gains and losses.

Extending our investigations to commonly used risky outcomes; we postulated a set of hypotheses. Negative outcomes framed as losses were expected to result in FRN, while positive outcomes framed as gains were not[3]. We expected framing to have a similar effect as context had in experiments, described in section 1.5.1.4. Positive loss framed outcomes were expected not to elicit a FRN response. Analogously, negative outcomes in frame of gains were expected to produce significant FRN. This expectation is further supported by the fact that in both framing conditions, positive outcomes constitute objective rewards, since they result in receiving the whole initial endowment. Negative outcomes, on the other hand, mean that there is no actual reward received in given trial, regardless of framing.

The attributes of our framing tasks allowed us to investigate ambiguity in 2 novel contexts - “all or nothing” and “always something”. Previous research has addressed

[3] Note that there are no objectively negative outcomes in framed gambles, when initial endowment is kept constant between framing conditions; no money is ever really lost. Negative loss framed outcomes indicate that whole initial endowment is lost, which results in no received reward. Gain framed negative outcome means that nothing of the endowment is kept, therefore the result is the same; objectively neutral. These outcomes, however, will be referred to as “negative outcomes”, despite their objective neutrality.

ambiguity between positive and negative outcomes only. Our paradigm provides us with tools to induce "certain" ambiguity, i.e. certain gains or losses of unknown magnitude, and "risky" ambiguity. The "risky" ambiguity, just like common risky options in framing effect tasks, has only two possible outcomes – negative and positive.

Assuming, that FRN reflects a binary evaluation of good or bad outcomes (Hajcak et al., 2006), gain framed ambiguous outcomes in the "always something" deals were not expected to produce FRN. Since the ambiguity only relates to the magnitude of positive outcome, no effect on valence processing was anticipated (Hajcak et al., 2006). Predicted FRN for loss framed ambiguous outcomes in the "always something" deals is dependent on observed ERP patterns associated with gain and loss framed deals with known outcomes. If differences in FRN are observed between gain and loss framed outcomes, this pattern might be replicated in ambiguous ones. In the case that descriptions will have no effect on the FRN responses, ambiguous outcomes in both frames should show no FRN.

Not too well grounded predictions can be made about FRN responses associated with ambiguous outcomes in the "all or nothing" context. Since objectively neutral outcomes were shown to elicit FRN when alternative outcomes are positive rewards (Holroyd et al., 2004), which is our case, negative deflection might be expected. Nevertheless, we refrained from formulating hypotheses and keep these results to be evaluated in an exploratory fashion.

2. Methods

Behavioral tasks and stimuli were first tested in a pilot research (N_p=5). Seventeen (N=17) female Croatian students (21-22 years old) participated in the main part of our experiment. Participants received a reward of 40kn (≈€5). They were instructed that the reward value depends on their performance in the experimental tasks to induce self-relevance of the outcomes. In a debriefing session, participants were informed of this experimental manipulation. E-Prime 2.0 was used for both stimuli presentation and behavioral data collection.

2.1. Pilot research

Various tasks, procedures and stimuli presentation styles were tested in the pilot research. The issues that were addressed in this phase included the overall structure of the session, display of materials and behavioral task for recording parts of the session. We dealt with confounds of duration, involvement, attentional and other related cognitive demands. Various versions of the tasks were tested on 4 subjects aware of our experimental setting. The final procedure was tested on 1 naïve subject. Criteria for duration and cognitive demands were met; therefore, it was adapted for the main experiment.

2.2. Procedure and materials

Our experimental session consisted of two parts, certain "always something" and risky "all or nothing". In each of them, participants first evaluated 40 risky or certain monetary deals. Afterwards, outcomes of the deals were presented to participants as stimuli in reward collection, during the EEG recording. The order of the parts of the experiment was randomized between subjects and separated by a 15 minute participation in an unrelated experiment. The overall experimental session duration was approximately 2 hours. Instructions were given separately for each task. To prevent

possible effects of language on cognitive and emotional processing, stimuli were translated into native language of participants, Croatian (Keysar, Hayakawa, & An, 2012)

Table 2.2.1. Probabilities and payoffs of stimuli used in evaluations

part	**endowment**	**probability / payoff**									
risky	20 30	20%	25%	30%	35%	40%	60%	65%	70%	75%	80%
certain	20	4	5	6	7	8	12	13	14	15	16
	30	6	7	9	11	12	18	19	21	23	24

Note: Probabilities of positive outcomes in risky and objective payoffs in the certain deals are specified.

The evaluation task served a purpose to obtain behavioral framing data and to induce context for the subsequent EEG recording sessions. The part with risky deals was composed of 40 items (2 frames x 10 levels of probability x 2 initial endowments). Certain deals were calculated to offer equal expected values, which again resulted in 40 items (2 frames x 10 payoffs x 2 initial endowments). Used levels of probability with matching payoffs in the certain deals are shown in table 2.2.1. and examples of displays are depicted in figure 2.2.1. The initial endowment manipulation (20/30 lp. ≈ €3/4 cents) was introduced to decrease stereotypicality. Participants submitted evaluations on a response pad. Four buttons corresponded to ordinal evaluation as "very bad", "bad", "good" and "very good". Reaction times were recorded along with responses.

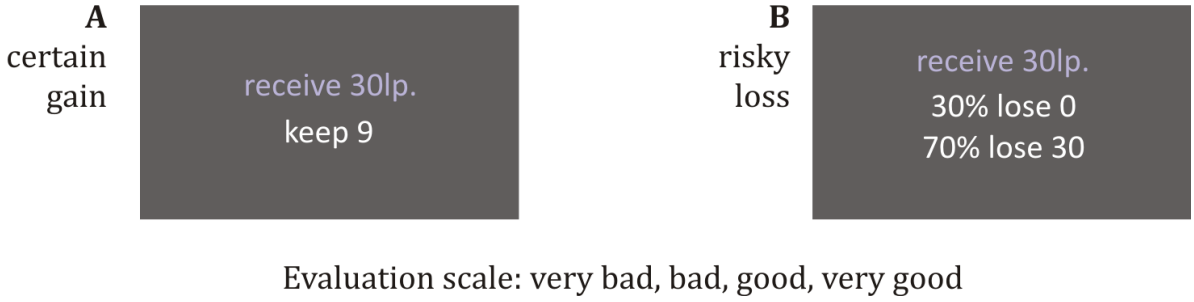

Figure 2.2.1. Displays of certain (A) and risky (B) deals presented in evaluations

Number of trials per condition was set at 40, since this number was shown to be more than sufficient for a stable FRN in healthy young subjects (Marco-Pallares, Cucurell, Münte, Strien, & Rodriguez-Fornells, 2010). The "all or nothing" part consisted of 240 trials randomly sampled into 4 blocks. The orders of blocks and items within blocks were randomized for each participant. Items covered 6 conditions: 2 frame (keep/lose) x 3 outcome (positive/ambiguous/negative). Participants were instructed that a selection of gambles from the previous evaluation is being put into a lottery and that they will learn outcomes of some of the gambles (keep 0, keep all (20 or 30), lose 0, lose all (20 or 30)), while some of them will not be shown (ambiguous - keep ? and lose ?). Outcomes presented in this part of the experiment are depicted in figure 2.2.2. After presentation of the outcome, they were given a choice to accept or reject each outcome into their final reward. Participants were instructed that only certain undisclosed number of outcomes could be collected, for them to make sense of the task in a controlled manner. After a display of one lottery outcome, participants were to decide, if they want to include it in their winnings or not. Obtained data was used to quantify, whether the outcomes were attained to, and as a measure of framing effect in ambiguity between "keep ?" or "lose ?".

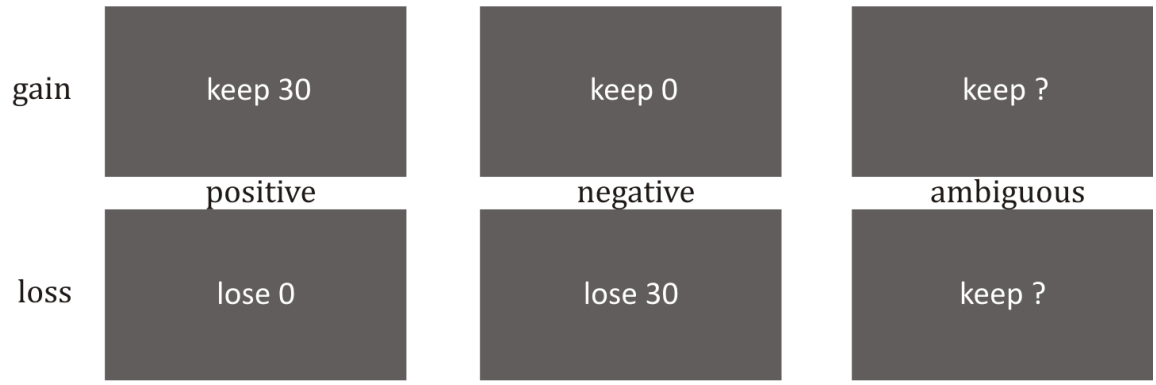

Figure 2.2.2. Examples of outcome feedback stimuli in the "all or nothing" part

Certain deals "always something" part was very similar to the risky deals part. It consisted of 160 trials divided into 2 blocks. The randomization procedure described above was used. Four conditions included: 2 frame (keep/lose) x 2 outcome

(known/ambiguous). Examples of outcome displays are shown in figure 2.2.3. Since lottery was not applicable in this context, participants were instructed that the deals in this part were chosen according to their preferences, just like in the risky part, and they will be able to choose which ones they want to count into their reward. Behavioral data was used for the same purposes as in the risky part, providing us with a measure of framing effect in ambiguity between keeping and losing unknown amounts of money. Additional index of framing effect, described in section 2.3., was obtained from these responses as well.

Figure 2.2.3. Examples of outcome feedback stimuli in the "always something" part

Both "all or nothing" and "always something" parts were preceded by a training session of 15 trials, where participants got familiarized with the task and were conditioned to blink on a beep to reduce the number of ocular artifacts in the recorded epochs of interest. After completion of the experiment, an interview was conducted. Participants rated items surveying their engagement and involvement in the task. Debriefing with a full disclosure was provided following the entire experimental session.

2.2.1. Stimuli

Stimuli in the two EEG recording parts were essentially the same. In each trial, participants received initial endowment 20/30 lp. Afterwards, an outcome feedback was presented, which contained information about how much of the endowment[4] is being

[4] The information about initial endowment (20 or 30 lp.) was colored differently than the outcomes. This coloring remained consistent in both evaluations and EEG recording reward collection tasks, just as is depicted in figures 2.2.1. and 2.2.1.1. Initial endowment introducing status quo is essential to create a genuine framing situation. Coloring was used to make sure, that this aspect of the monetary deals is not overlooked by participants. Indeed, if the endowment was ignored, framing effect investigation would be reduced to objective gain and loss research.

kept or how much was lost. The only difference was that stimuli in the "always something" part offered rewards ranging from keep 6 to keep 26 or lose 4-24 (see table 2.2.1.), while in the risky "all or nothing" part, only "keep 0" or "keep all" and "lose 0" or "lose all" could result from gambles. Both parts included "keep ?" and "lose ?" stimuli.

Inter stimulus interval (ISI) was randomized in a range 600-800 ms and was accompanied by a fixation cross display. One hundred milliseconds before the screen with initial endowment, a 400 Hz beep was played as a conditioned stimulus to elicit a blink to prevent from blinking in the analyzed segments. Screen with initial endowment was displayed for 1 s, followed by a 1 s baseline blank screen. The outcome feedback was displayed for 1 s, followed by 500 ms blank screen and a prompt to accept or decline including the given outcome into participant's overall winnings. A structure of a trial is depicted in figure 2.2.1.1.

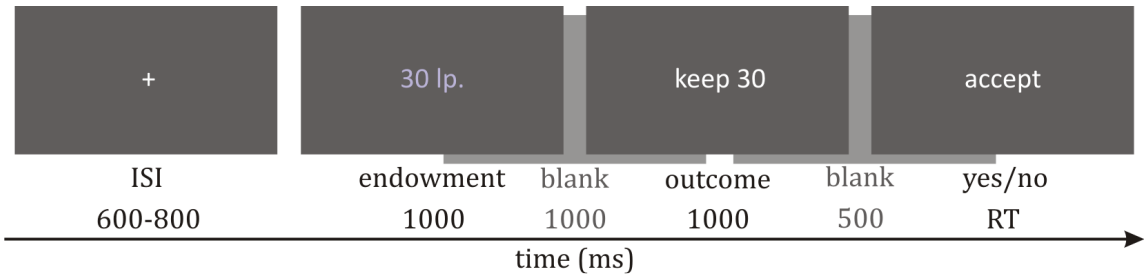

Figure 2.2.1.1. Structure of a trial in EEG recording sessions

2.3. Behavioral measures

Three measures of framing effect were used. The answers from the evaluation tasks were used to determine how framing affected evaluations of certain deals and risky gambles on bad-good dimension. In the "always something" EEG recording part, additional measure was used to compare tendency to accept and reject equal, but differently framed outcomes. In both "all or nothing" and "always something" parts,

proportion of accepted ambiguous outcomes constituted a measure of framing in an ambiguous situation.

Reaction times were collected with each response. Trials in which the reaction times were more than 2 seconds longer than the second highest reaction time were excluded in order to minimize the influence on averages by outliers, most likely produced by unrelated factors, such as scratching.

To verify whether the participants tried to maximize their winnings, two measures were developed. In the "all or nothing" part, accepting positive outcomes and rejecting negative outcomes was considered correct. This method resulted in 160 trials, where correctness was assessed. In the "always something" part, best and worst outcomes were identified. The possible payoffs ranged from 4 to 26. Outcomes with payoffs lower than 7 were labeled as the worst, whereas payoff amounting to 18 and higher as the best. This resulted in 32 trials out of 80 with known outcomes, which were used to assess success in maximizing winnings in the "always something part". Participants were expected to fulfill both performance criteria to at least 80% to be included in analyses of these parts of the experiment.

2.4. EEG recording and analysis

EEG was recorded with a Brain Products actiCAP 32-channel system with Ag/AgCl electrodes mounted in a lycra cap according to 10-20 System. Vertical electrooculagram (VEOG) was recorded from a bipolar electrode placed above and below right eye. The electrode impedances were maintained below 20 kΩ throughout the sessions. Recording was sampled at 1,000 Hz. The data was online referenced to common average with band-pass filtering on the EEG electrodes 0.1-70 Hz and additional 50 Hz notch filter. The VEOG electrode was band-pass filtered at 0.1-100 Hz.

In the offline analysis, the data was re-sampled to 500 Hz to increase the speed of data analysis. Data was filtered to 0.5-40 Hz on all EEG electrodes. Electrodes with especially noisy readings were further low-pass filtered to 30-20 Hz based on individual consideration to prevent detection of false artifacts during automatic procedures. Since mastoids recordings were in general noisier than our electrodes of interest, left and right mastoids were low-pass filtered to 15 Hz. Automatic independent component analysis ocular correction algorithm trained on entire individual datasets was performed to correct for eye blinks.

Intervals exceeding maximal voltage step 50 µV/ms, difference in 200 ms intervals higher than 200 µV, activity in 100 ms lower than 0.5 µV and amplitudes higher/lower than +/-150 µV were excluded from the analysis with an automatic raw data inspection. One second intervals around markers (200 ms baseline) were extracted separately for each experimental condition. Additional automatic artifact rejection was run to exclude segments, where any of the EEG electrodes exceeded 100 µV difference in a period of 200 ms, to remove intervals insufficiently corrected for ocular artifacts. Intervals were baseline corrected to 200 ms before outcome feedback onset and re-referenced to left and right mastoid electrodes. Additional 2 Hz high-pass and 20 Hz low-pass filtering was applied prior to averaging intervals within conditions (Hajcak et al., 2006).

Based on visual inspection of the grand averaged waveforms, a time window of 230-330 ms after reward onset was defined as an interval for average amplitude measure of FRN (Peterburs, Suchan, & Bellebaum, 2013). FRN was quantified on two electrodes (CZ and FZ), where the effect was anticipated (Holroyd et al., 2004).

3. Results and discussions

Prior to the main data analysis, all variables were examined for a possible effect of task presentation order. Independent sample T-test and familywise adjusted p values with Bonferroni correction (separately for responses and reaction times, within tasks) showed no significant effect of order on any variables. The order of the tasks was therefore excluded as a between-subject factor in all the analyses.

Since the evaluation task and tasks during EEG recording both include measures of framing effect and reaction times, results are reported and discussed separately to avoid confusion. First, evaluation part of the experiment, where participants evaluated certain and risky options on a 4 point scale is analyzed and discussed. EEG recording session results, including behavioral data, are reported and discussed afterwards.

3.1. Evaluations

Average ratings of certain and risky deals on a 4 point bad-good dimension were compared between framing conditions. Additionally, differences between evaluations of certain and risky deals were explored. Negative values represent negative ratings of deals (-2 = “very bad”, -1 = “bad”) and positive values represent favorable rating (1 = “good”, 2 = “very good”). Note that neutral answer (0) was not an available evaluation.

3.1.1. Results

One participant from pilot testing was included in an analysis, while one from the main experiment was excluded due to a corrupted data file, resulting in N=17. Wilcoxon signed-rank test was used to assess the significance of differences.

No significant effect of frame neither in certain Z=-0.97, nor in risky deals Z=-1.13 was observed (see table 3.1.1.1.). The rating of risky deals (Mdn=0.1, IQR=0.1) were more favorable than rating of certain deals (Mdn=-0.2, IQR=0.5), Z=-2.57, p=.008.

Correlation coefficient r_m=.540 suggest a rather large effect size. Overall evaluations were, however, rather close to neutrality.

Table 3.1.1.1. Comparison of evaluations

deal	frame	Mdn	IQR	Z	p	Mdn	IQR	Z	p	r_m
certain	gain	-0.1	0.6	-0.97	.350	-0.2	0.5	-2.57	.008	.540
	loss	-0.1	0.4							
risky	gain	0.1	0.1	-1.13	.261	0.1	0.1			
	loss	0	0.2							

Two-way repeated measures 2x2 ANOVA was conducted to determine effects of frame (gain/loss) and deal (certain/risky) on reaction times of evaluation. Main effect of frame $F(1,16)=15.40$, $p=.001$, $\eta^2=.490$ revealed that participants took longer to evaluate deals described as losses (M=4602 ms, SE=197)[5] than those described as gains (M=4136 ms, SE=159). Main effect of type of deals was significant as well $F(1,16)=128.27$, $p<.001$, $\eta^2=.889$. Participants responded faster, when they were evaluating certain deals (M=3005 ms, SE=172) as compared to risky deals (M=5734 ms, SE=238). The interaction between type of deal and frame fell short of significance $F(1,16)=3.83$, $p=.067$, $\eta^2=.194$, indicating a possible differential effect of frame on the kind of deals, however, with a significantly smaller effect size, as compared to the main effects.

3.1.2. Discussion

Framing had no effect on evaluations of risky options, just as was expected. However, contrary to our prediction, evaluations of certain options were not affected by framing either. Prior to discussing theoretical implications, we consider it prudent to analyze characteristics of our task that might have confounded framing manipulation.

Comparison of experimental designs between our experiment and the experiments conducted by Kühberger & Gradl (2013) reveals a possible source of discrepancy in the

[5] Estimated marginal means and standard errors (SE) are reported along with ANOVAs.

results. Pattern of framing effects predicted in our hypothesis was based on between-subject experiments, in which each subject not only evaluated options in one frame, but also just within a single problem. However, in our designs, participants made 20 evaluations in each framing condition. We argue that this experimental setting might have elicited adaptation of simple strategies that could have prevented framing biased responses as a byproduct.

In each session where participants submitted evaluations, they were faced with very similar stimuli. Indeed, besides from framing, only payoffs were varied in the certain deals and probabilities were manipulated in the risky deals. Initial endowment manipulation was included in both of these sessions to help us distract participants from experimental manipulation. Nevertheless, these systematic differences were virtually impossible to miss. It is likely, and supported by several participants in post-experiment interviews, that policies regarding valence of the evaluation were soon developed in the process of completing the task. Some of the explanations stated by participants were along these lines: "When I could keep more than a 'threshold', I evaluated it as good, when it was less, I pressed bad." Similar strategies were reported after evaluation of risky deals: "When probability to keep all was more than 'threshold', I evaluated it as good."[6]

We suggest that our task induced comparative evaluations between deals in given sets, both certain and risky. Further evidence to support the interpretation based on setting thresholds for evaluations observed in our experiment are the central tendencies and dispersions of evaluations. The median evaluations were fairly close to neutral in both risky and certain deals. The probabilities in the risky options were equally distributed around 50%. Since payoffs in the certain options were calculated to offer

[6] These paraphrases of participants' reports are framed as gains; however, several participants also reported making calculations of how much is left of the initial endowment, when options were framed as losses during evaluations and subsequent EEG recording tasks. This might suggest that objective reward directed perspective was adapted.

equal expected values, they were, similarly, equally spread around one half of the initial endowment. Therefore, setting ½ of either initial endowment as a criterion or 50% probability, would correspond to distribution pattern of values in our stimuli. If other thresholds as those around 50% probability or ½ of initial endowment were adapted, median evaluations further from neutrality would be expected. The low variability in evaluations of risky option would suggest that indeed, a threshold around 50% could have been chosen by several participants, as a criterion for valence evaluation. Probability information is readily available and invariant between the two levels of initial endowments. On the other hand, a strategy to be adapted for the certain deals might have been more influenced by variations of initial endowment, making it more difficult to formulate such a straightforward criterion. Even if a strict "more than ½ kept = good" evaluation rule was adapted, it would be more susceptible to trial-to-trial comparison influences and computationally more complex, thus more error-prone, which might account for the increased dispersion of evaluations.

Despite the likely impact of simple strategies on evaluations of favorability, we suggest that they were rather valence based and no such reliable policies were being adapted for evaluation of degree ("good" and "very good", "bad" and "very bad"). Nevertheless, we believe that such strategies could have introduced a confounding factor for our design and decreased its ability to detect framing effects.

Inconsistence of this observation with results of Kühberger and Gradl (2013) might be explained by differences between Asian disease problem and gambles. In Asian disease problem with 600 lives in jeopardy, certain option "200 lives will be saved" does not necessarily mean that people faced with this option expect exactly 200 lives to be saved. Research on framing effect assumes that being faced with an option describing 200 lives being saved is equivalent to 400 people will die. However, it seems that people in some instances interpret an certain option in a way that "200 lives will be saved now and some more may be saved later" (Kühberger & Tanner, 2010). Therefore it might be argued that the two descriptions do not convey equivalent information (McKenzie,

2004). Indeed, a review of risky choice framing experiments in which complementary outcome were presented in the certain option of Asian disease-like problems in the certain option suggests that adding this information eliminates framing effect (Kühberger & Tanner, 2010). Addition of complementary information, however, might arguably have no effect in gambling tasks. Differences in domains of lives and money might result of different interpretation of unspecified information. It seems reasonable to assume that a message "keep 20 cents" would not be interpreted as "keep 20 now and maybe keep some more later". Furthermore, it seems to be even less likely in our task, where participants were repeatedly confronted with both formulations of the options, thus increasing their awareness of the complement. To our knowledge, this possible difference between effects of adding complements to certain option on problems involving money and human lives has not been tested before and might be an interesting avenue for future research.

Certain option might satisfy the condition of information equivalency between frames in gambles, however not in problems dealing with human lives. This could possibly account for the inconsistency between our findings and Kühberger and Gradl (2013). Nevertheless, even if that is the case, stimuli very similar to ours used in a risky choice framing task have been shown to result in framing effect even in within-subject designs, where participants were faced with the same decision repeatedly (De Martino et al., 2006; Zeng et al., 2013). It might be possible, that framing effects observed in risky choice task arise from choice processes rather than differences in evaluations of options (Kühberger & Gradl, 2013). Indeed, consistence of evaluations with choices in Kühberger and Gradl (2013) does not necessarily mean that differences of evaluations directly caused framing in choices. Combining attribute framing and risky choice framing with gambles, as was done previously with Asian disease problem (Kühberger & Gradl, 2013) might bring new insights into this issue. If the lack of attribute framing in separate evaluations of options in gambles from our research is replicated in an experiment, where a choice task is included and risky choice framing persists, it could

mean that attribute framing on evaluation of separate option might be coinciding with risky choice framing, rather than being a cause of it.

The observation that negatively framed deals elicited longer reaction times suggests that participants exerted more cognitive effort during processing. This is consistent with our predictions based on assumed influences of negative affect on tendency to more elaborate information processing. However, we suggest that our task itself might have had this effect, which could be independent from framing effects. When deals were framed as gain, the information about the resulting reward was readily available, without any need to consider the amount of initial endowment. On the other hand, this was not the case in negatively framed outcomes. To understand, what the results of loss framed outcomes are, participants might have considered the initial endowment received in given trial and subtract the loss, to obtain information comparable to that readily available in the frame of gains. Indeed, some of the participants reported making this calculation in the post-experiment interview.

If the observed differences in reaction times were a result of asymmetry of information availability, reversing this asymmetry could result in different patterns of reaction times. Taking our stimuli as an example, a simple modification can be made to achieve just that. Turning initial endowment into an initial loss on each trial would give messages framed as losses informative advantage. However, gain framed messages, such as “keep X” would suffer the same information availability limitations as did frame of losses in our materials. The magnitude of initial loss would be of informational relevancy only in the frame of gains. Comparing reaction times between tasks where loss framed information conveys information more directly, just like in the proposed task, with one gain framed messages would have similar attributes in this respect, might help in isolating genuine effects of framing on reaction times. We argue that in our task, it was not only the framing condition that varied, but also the availability of information relevant to the task performance.

Nevertheless, even if it was information availability that contributed to prolonged reaction times in loss framed evaluations, it cannot account for differences observed in the "all or nothing" evaluation part of our experiment. The information about possible positive outcomes ("keep all"/"lose 0") and negative ones ("keep 0"/"lose all") had essentially no difference in relation to initial endowment. Indeed, the initial endowment magnitude information was redundant, since it was repeated in the possible outcomes (note that exact information displayed along with the probabilities was: keep all = "keep 20" or "keep 30", lose all = "lose 20" or "lose 30"). Therefore, despite no more calculations were necessary to obtain the information about actual outcomes; reaction times were longer in the frame of losses. This observation supports the proposition that negative framing might have genuine effect on cognitive effort.

Observation that risky deals elicited longer reaction times than the certain ones is of little theoretical interest. Nevertheless it provides us with some more evidence to the point that participants did, indeed, attend to the presented material. Since risky deals displays contained significantly bigger amount of information, longer processing was to be expected.

Our results suggest that framing had no effect on evaluations or neither certain, nor risky options. Experimental task, however, might have confounded the sensitivity of our behavioral measures of attribute framing effect. The significance of decision or evaluation context and setting on comparing experimental evidence is discussed in more detail in the general discussion. Negative framing reliably increased response times, which might indicate that more cognitive effort was exerted when loss framed deals were being evaluated.

3.2. Reward collection

All data collected during EEG recording "reward collection" part is analyzed and discussed in this section. Framing effect measures based on tendency to accept

ambiguous outcomes in both “all or nothing” and “always something” parts are included in the behavioral data analysis, along with additional measure of framing effect obtained in the “always something part”.

3.2.1. Behavioral results

First, the criteria described in section 2.3. are evaluated to confirm that participants tried to maximize their winnings, during “reward collection” part of our experiment. After presenting results of additional framing effect measure of certain outcomes obtained from participants’ decisions whether to accept or reject outcomes, we analyzed framing effects on tendency to accept ambiguous outcomes in both “all or nothing” and “always something” parts. Reaction times were analyzed to determine effects of framing, outcome (positive/negative/ambiguous) and context on the response speed.

In the “all or nothing” part, all but 2 participants scored 7 points and lower in the error index, which is well below our boundary (32). Remaining 15 were very successful in accepting outcomes where they kept the whole initial endowments a rejecting those which brought them no reward. However, 2 participants scored 65 and 82 error points out of theoretical maximum (t.m.) 160, suggesting responses close to random in the task. These participants were excluded from any further analyses in both parts of the experiment.

The error rate during the “always something” part was lower and no participant exceeded the set threshold (7). All but 1 participant rejected a very good or accepted a very bad deal twice at most.

When participants had an option to accept or reject outcomes in the “always something” part, they were more inclined to accept outcomes framed as gains rather than those described as losses $t(14)=2.67$, $p=.018$, $d=0.97$. On average 57% of gain framed outcomes were accepted ($M=23$, $SD=4$, t.m.=40), while only 52% with negatively described were accepted ($M=21$, $SD=3$, t.m.=40).

Exploratory analysis of framing effects and deal context ("all or nothing"/"always something") on ambiguity was performed in a similar manner. In a two-way 2x2 ANOVA, frequencies of accepted ambiguous outcomes were compared. Participants' tendency to accept ambiguous outcomes was equal in both parts of our experiment $F(1,14)=1.90$. However, a main effect of frame $F(1,14)=11.66$, $p=.004$, $\eta^2=.454$ revealed that more ambiguous outcomes were accepted in the frame of gains. Less than 38% of ambiguous outcomes framed as losses were accepted (M=15, SE=2, t.m.=40), however, in the frame gains, 65% of outcomes were chosen to be counted into own rewards (M=26, SE=3, t.m.=40). The interaction between the factors was completely insignificant $F(1,14)=0.00$.

Reaction times in all condition of the "all or nothing" part were analyzed to compare effects of outcomes (positive – "keep all" or "lose 0", ambiguous -"keep ?" or "lose ?", negative - "keep 0" or "lose all") and framing. Two way 2x3 ANOVA was performed with 2 levels of framing and 3 levels of outcome constituting the within-subject factors. Mauchly's test of sphericity was calculated and Greenhouse-Geisser correction was applied where appropriate. Bonferroni correction was used in subsequent pairwise comparisons.

The main effect of frame $F(1,14)=26.29$, $p<.001$, $\eta^2=.653$, revealed that negatively framed outcomes were associated with longer reaction times (M=744 ms, SE=67) as compared to positively framed outcomes (M=692 ms, SE=63). Significant main effect of outcome $F(1.2,28)=6.93$, $p=.015$, $\eta^2=.331$ suggests, that reaction times differed between positive, negative and ambiguous outcomes. Subsequent pairwise comparisons showed that reaction times were shorter for positive outcomes ("keep all" and "lose 0" – M=674 ms, SE=66) than for both ambiguous $p=.026$[7] (M=847 ms, SE=100) and negative outcomes $p=.014$ (M=736 ms, SE=71). Differences between ambiguous and negative outcomes were insignificant. Interaction between frame and outcome $F(2,28)=3.57$,

[7] Reported p values are corrected for multiple comparisons.

p=.042, η^2=.203 indicates that framing did not have equal effect on all outcomes. Inspection of figure 3.2.1.1. shows, that framing effect on reaction times was not present in negative outcomes.

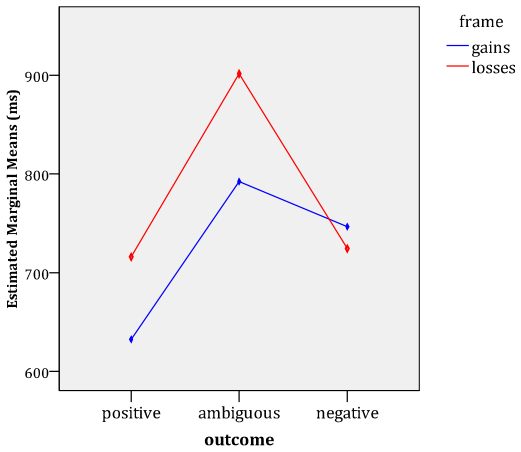

Figure 3.2.1.1. Reaction times in "all or nothing" part

Finally, reaction times to positively and negatively framed known and ambiguous outcomes were compared in the "always something" part. Two way repeated measures 2x2 ANOVA with frame (gain/loss) and outcome (known/ambiguous) was conducted. The main effect of frame F(1,14)=17.14, p=.001, η^2=.550 corresponded to results from previous analysis of reaction times, confirming that participants took longer to response in negatively framed (M=836 ms, SE=73) than to positively framed outcomes (M=773 ms, SE=68). Insignificant main effect of outcome F(1,14)=0.31 shows that there were no differences in speed of reaction to known and ambiguous outcomes. Lack of two-way interaction of outcome with framing suggests that the effects of frame on reaction times did not differ between outcomes in the "always something" part F(1,14)=3.46, unlike in the "all or nothing" part.

The main results of our behavioral data analysis show that participants were a little more prone to accept positively framed outcomes in the "always something" part than those framed as losses. In both parts of the experiment they equally preferred ambiguous gain framed outcomes, as well. Negative framing reliably resulted in longer reaction times in both part of the experiment. However, in the "all or nothing" part,

negative outcomes ("keep 0" and "lose all") did not differ in reaction times between framing conditions. Positive outcomes in both frames in the "all or nothing" part resulted in shorter reaction time than ambiguous or negative ones. No such difference between outcomes in the "always something" part was observed.

3.2.2. Feedback-related negativity

Feedback-related negativity was analyzed on Fz and Cz electrodes. Mean amplitudes in the time window 230-330 ms were compared separately for 6 conditions in the "all or nothing" and 4 condition is the "always something" part. Since the data violated the assumption of parametric tests, the values were normalized using natural logarithm. Untransformed observed values are reported as descriptive statistics.

Repeated measures 2x3 ANOVA was used to assess differences in FRN in the risky outcomes conditions. None of the main effects of frame or outcome (positive, negative, ambiguous) in the "always something" part reached statistical significance on the Fz electrode $F(1,14) \leq 3.74$, and neither on the Cz $F(1,14) \leq 1.98$. The similarity of measured ERP waveforms is readily visible in figure 3.2.2.1.

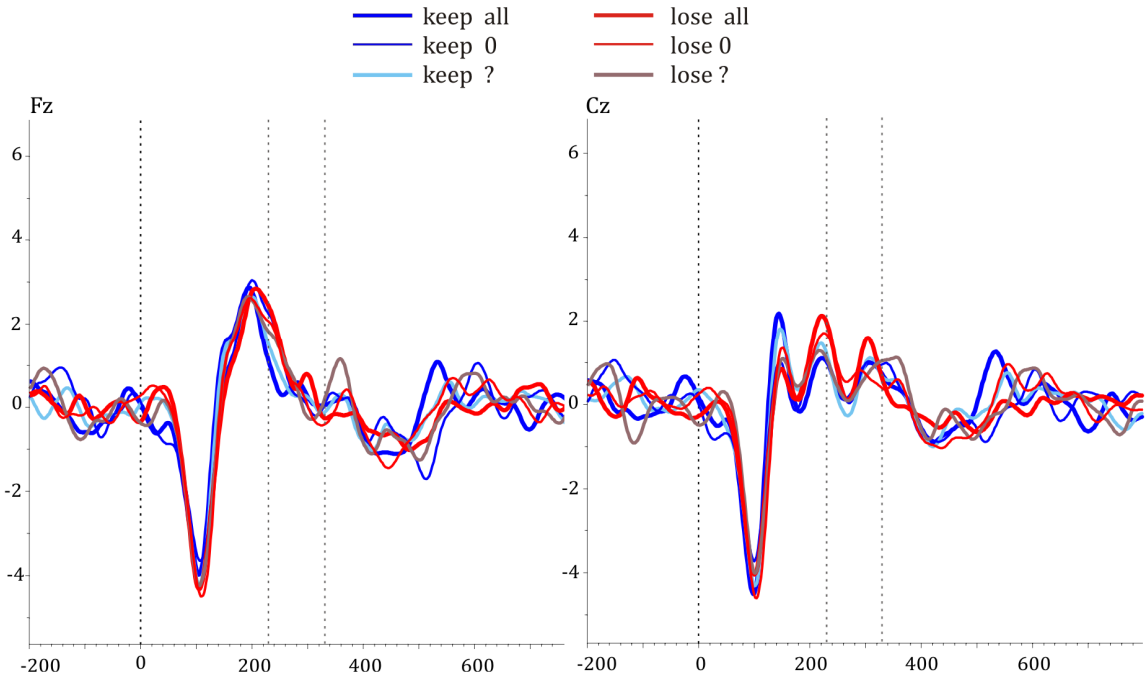

Figure 3.2.2.1. ERP waveforms in the "all or nothing" part

A separate 2x2 ANOVA was performed in the "always something" part of the experiment. On the Fz electrode, the main effect of frame was not significant $F(1,14)=0.19$. However, difference between known and ambiguous outcomes was significant $F(1,14)=17.74$, $p=.001$, $\eta^2=.559$, indicating lower mean amplitude for ambiguous outcomes (M=-0.267 ηV, SE=0.292) as compared to outcomes with known reward, irrespective of framing condition (M=0.533 ηV, SE=0.383). Similar results were observed on the Cz electrode; main effect of frame was insignificant $F(1,14)=0.74$, while main effect of outcome was present $F(1,14)=9.00$, $p=.010$, $\eta^2=.391$ (see figure 3.2.2.2.). Furthermore, a significant interaction between outcome and frame on the Fz electrode $F(1,14)=5.45$, $p=.035$,$\eta^2=.280$ and subsequent pairwise comparison analysis revealed that significant differences, with Bonferroni correction applied on p values, are not present in comparison of positively framed known and ambiguous outcomes. The interaction was insignificant on the Cz electrode $F(1,14)=2.96$.

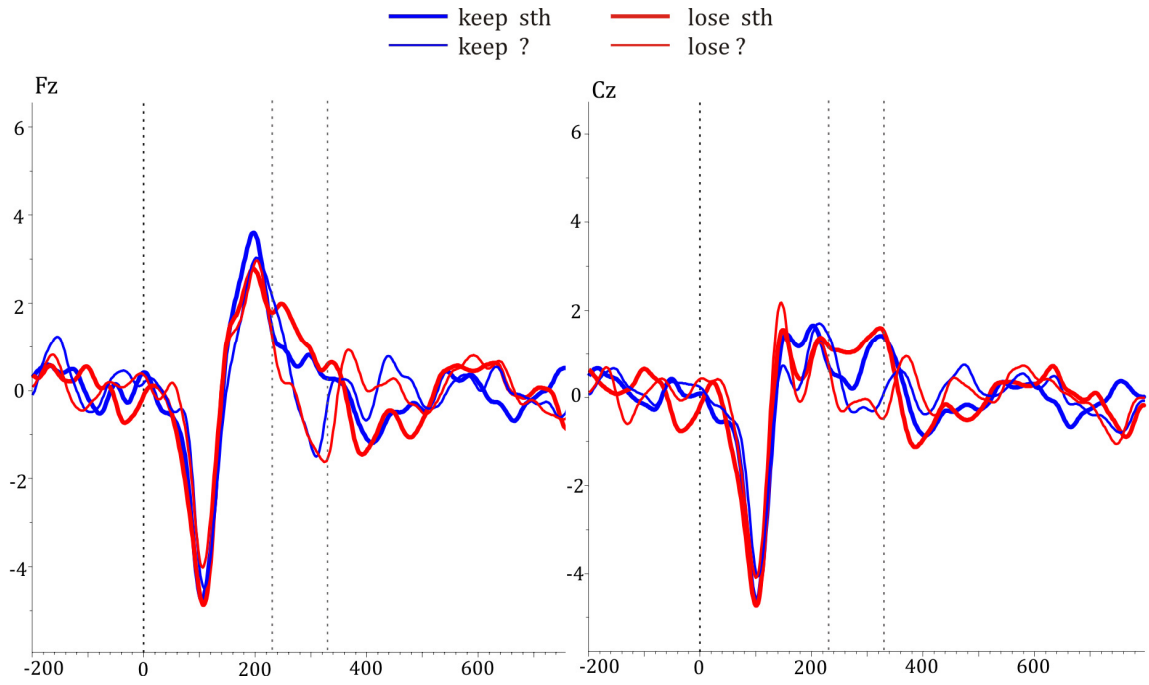

Figure 3.2.2.2. ERP waveforms in the "always something" part

No effects of framing or outcome were observed in the „all or nothing" part of the experiment. In the „always something" part, main effect of outcome revealed, that FRN

was stronger in ambiguous outcomes, as compared to those with a known reward. To illustrate the differential effect of ambiguity in the two parts of our experiment, waveforms associated with ambiguous outcomes are depicted in figure 3.2.2.3.

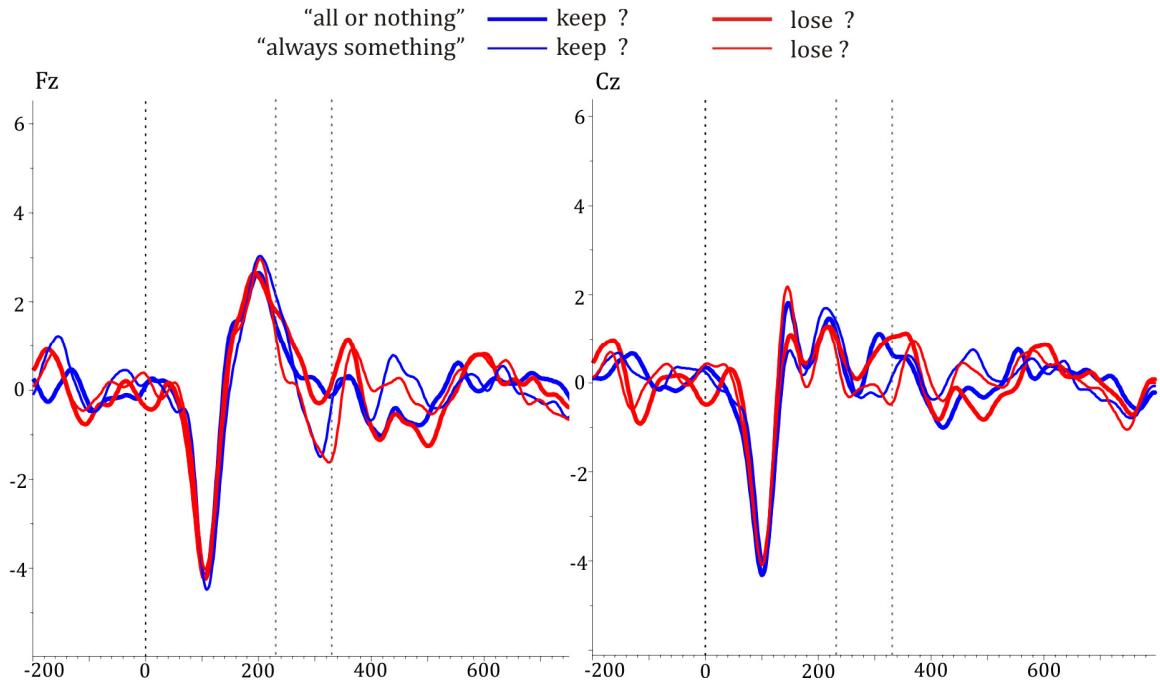

Figure 3.2.2.3. ERP waveforms for ambiguous outcomes – both parts

3.2.3. Discussion

Framing effects were observed in acceptance rates of known outcomes in the "always something" part and ambiguous outcomes in both parts, where it was significantly more pronounced. Note that no such measure was included in the "all or nothing" part of our experiment. Negative frames elicited longer overall reaction times, which is in accordance with our prior expectations. However, in the "all or nothing" part, interaction with outcome suggests a more perplexing pattern of effects on reaction times.

No effects of outcome feedback on FRN were found in the "all or nothing" part. The lack of differences between positive and negative outcomes unexpected and casts a shadow of doubt on appropriateness of our procedure and stimuli to investigate FRN.

Absence of framing effect on FRN amplitude in the "always something" part was contrary to our prediction and in conflict with previous results of Ma et al. (2012). Since no framing effect on the FRN was observed, its absence was expected for ambiguous outcomes as well. Indeed, no difference in the FRN amplitude was found between gain and loss framed ambiguous outcomes in the "always something" part, while ambiguity in general elicited a negative deflection. This observation suggests that even ambiguity referring to magnitude of an outcome might be reflected in FRN. The inconsistency of our results with predictions for the "all or nothing" part, however, requires a more thorough explanation and is addressed first.

Previous experiments have found FRN associated with ambiguity between gains and losses (Gu, Ge, et al., 2010; Gu, Huang, et al., 2010; Hirsh & Inzlicht, 2008; Holroyd et al., 2006). Despite that ambiguity was rather an explorative aspect of our study, the a priori probability would suggest the FRN to be more likely, when the ambiguity is between objectively positive and neutral outcomes rather than only those indicating ambiguity about magnitude of positive outcomes. This a priori difference is based on the observations that neutral outcomes result in FRN when presented in context of positive ones (Holroyd et al., 2004) and that FRN negativity reflects valence and is not really sensitive to outcome value (Hajcak et al., 2006). The discrepancy between FRN responses to ambiguous stimuli in the "all or nothing" and "always something" parts goes contrary to these expectations.

Confounding variables that might have contributed to unexpected FRN results in the "all or nothing" part and discrepancy between effects of ambiguity between the two parts of our experiment are analyzed first. Characteristics of our tasks and observed reaction time patterns are investigated as possible indicators of task processing differences between the two parts of our experiment.

Negative outcomes in the "all or nothing" part ("lose all" and "keep 0") were expected to produce a FRN. Our results reveal that this was not the case. As the first possible explanation, we consider a possible effect of our task. We suggest that allowing

participants to reject outcomes might have rendered the negative outcomes self-irrelevant, thus reducing the effects on FRN. Self-reported ratings of involvement in a task were shown to be correlated with FRN amplitude (Yeung, Holroyd, & Cohen, 2005), however, not to such a degree that it would disappear. In the experimental task, participants were expected to reject the negative outcomes. Participants who failed to do so were excluded and the remaining ones were very successful. Therefore we hypothesize that awareness of the opportunity to reject outcomes and prior decision to do so was adapted by participants as a simple policy. This policy might have affected the processing to such extent that the outcomes would be considered irrelevant from the motivational and affective perspective, which is supposed to be reflected in the FRN. This proposition has a directly testable corollary. If it was the ability to refuse the negative outcomes, FRN should re-appear when the task would not provide this option and would be of only evaluative nature, such as evaluating outcomes as good or bad. Indeed, if such an experiment was conducted, it would bring new insight about the magnitude of FRN modulation by self-relevance of the outcomes influenced by top-down processes.

Nevertheless, even if it was the insufficient motivational and affective impact of negative outcomes that caused the lack of FRN for negative outcomes, it can hardly explain the equality of ERP waveforms for positive and ambiguous outcomes in the "all or nothing" part. Behavioral results confirming that participants reliably rejected negative outcomes might be of some explanatory bearing on the non-presence of associated FRN. However, this argument cannot be applied to ambiguous outcomes, where participants accepted roughly the same number of them in both parts of our experiment in a framing effect consistent pattern. Therefore, we speculate that similarity of ERP waveforms could have been a result of significantly different cognitive processing in the two parts of our experiment.

The "all or nothing" part had, indeed, correct and incorrect responses. Trials where participants were able to keep the whole initial endowment were good and in an

attempt to maximize the winnings, it would be advisable to accept them. The outcomes, where they either lost everything or kept nothing, on the other hand, were bad and rejecting them was expected. Participants' responses seem to correspond to this perspective. The measure of correctness in the "always something" was more arbitrary. The degree of "goodness" that we adapted to measure their effort to maximize the winnings was based on criteria relative to the distribution of outcomes, since each and every outcome offered an objective gain. We argue that the outcomes in the "always something" part had to be processed and evaluated individually, while the outcomes in the "all or nothing" part allowed for a more direct stimulus-response based task processing.

Essentially, we propose that the participants in the "all or nothing" part were "hunting" for the positive outcomes as for target stimuli, while considering the other ones non-targets. We speculate that this explanation might account for the lack of FRN associated both with negative and ambiguous outcomes, since the target identification and response might have preceded evaluative processes under investigation. This point has support in obtained measures of reaction times. Indeed, the reaction times were shorter for positive outcomes than both negative and ambiguous in the "all or nothing" part, while it was not the case for the "always something" part. We suggest that the speeded reaction for positive outcomes might be indicative of target focused attention. When the target was not identified, other processes, possibly including the evaluative ones which were of our interest, might have followed. However, responding to targeted stimulus might have either delayed or interfered with the evaluation processes. We propose that this unanticipated effect of the task could have affected cognitive processing to the degree, where FRN responses to outcome feedback evaluation might be too confounded by unrelated processes.

We conclude that confounding variables likely related to unanticipated cognitive processes induced by the task in the "all or nothing" part made it impossible to verify our hypotheses regarding FRN patterns associated with conditions included there.

Nevertheless, results from the “always” something part allowed us to evaluate some of our predictions.

No significant differences in FRN responses to equal, objectively positive but differently framed, outcomes suggest that framing effect might not be reflected in the FRN amplitude. Despite the lack of differences in the FRN, small framing effects were observed in behavioral responses. Ma et al. (2010) argue that the valence-based associative processing may be related to neural substrates of FRN. Our results found no such association. The responses to known outcomes, however, exhibited too small framing effect to be considered evidence against this claim. Assuming that differences in materials between the experiments are the cause of this discrepancy, two lines of interpretation are proposed.

As was discussed in the section 3.1.2., monetary and life-death problems might be unequal, when it comes to interpretation of unspecified outcome complement. Repetition of gain and loss framed outcomes was argued to have possibly increased the awareness of the complement and interpretation of outcome as an exact one in the evaluation task. However, this same factor was present in the experiment examining FRN in the Asian disease problem, as well (Ma et al., 2012). Therefore, it might be less likely that the outcomes were interpreted as inexact, even in life-death scenarios. Nevertheless, if the discrepancy in FRN and behavioral framing effects between the two experiments were results of complement interpretation, FRN associated with frames of losses might have been elicited by expectations of even worse outcomes than those explicitly described in Asian disease problem (Ma et al., 2012).

Another possible explanation is related to differences between the Asian disease problem and gambles mentioned in the section 1.1. While gambles involve initial endowment, the Asian disease problem introduces initial loss, a quantity of people dying. Perhaps positive description can induce impression of gain, decreasing the FRN amplitude, when objective outcomes are losses. Contrarily, negative framing might not have this effect when objective gains are concerned. If it is not the domain of life or

money, which caused the discrepancy between experiments, but the valence of status quo before the outcome occurrence, replicating our experiment with initial losses might reveal framing dependent FRN responses.

The FRN-like reaction for ambiguous stimuli in the "always something" part as compared to known stimuli might indicate a more profound role of ambiguity in processing indexed by FRN than could have been expected from previous experiments. Experiencing known outcomes seems to differ from experiencing ambiguous ones, despite that the valence of the outcome is certainly positive. If our participants perceived the task as a calculation task, which we suggest that at least some of them did, ambiguous outcomes did not allow this goal to be completed and therefore might have been processed as "bad"[8]. The presumed affective and motivational processes related to FRN could in this case reflect the frustration from inability to complete the task in a desired way. However, the unresolved outcome might play a role in the reward system. Even the magnitude ambiguity could be processed negatively by the midbrain dopamine system; since it may lack the information needed to compare expected and received rewards. Our results would need to be replicated in different tasks to assess this hypothesis.

Difference between known and ambiguous stimuli in the "always something" part might, however, have influenced the ERPs in an unintended way. While the known outcomes consisted of 20 different stimuli repeated twice in each frame, the ambiguous conditions repeated the same stimulus 40 times. This variation might have affected ERP components separate from FRN. For example, frontal P3-like component was shown to be related to unexpected stimuli (Luck, 2005), which might have increased the amplitude in the time window under investigation for outcomes with known magnitudes, due to high variance of stimuli. It could be argued that the difference in amplitude observed between known and ambiguous stimuli was rather related to

[8] We are grateful to Kristína Rebrová for proposing this line of interpretation.

differences in novelty than processing indexed by FRN. Nevertheless, variability of stimuli within ambiguous and known conditions was equal. Therefore, inferences related to FRN between framing conditions should be unaffected by stimulus novelty.

Lack of framing effects on FRN was associated with ambiguous outcomes, while rather pronounced preference reversal was apparent from participants' responses. This dissociation of behavioral and FRN measures suggests, that framing effect consistent behavior might be results of processes unrelated to those indexed by FRN. We suggest that framing effects may coincide with FRN, as it did in the previous experiment (Ma et al., 2012), but other processes could be involved as well. What our results indicate as likely is that framing effect consistent responses are not necessarily accompanied by differences in FRN.

4. General Discussion

Absence of observed attribute framing effects in evaluations of both certain and risky monetary deals, constructed to resemble decision options used in risky choice framing experiments, might indicate that monetary gambles and life-death "gambles" differ in some way. Possible dissimilarities in respect to information equivalence are discussed in section 3.1.2.. This hypothesis is, however, based on comparison of experiments with fundamentally different designs. Likely influences of within- and between-subject designs are considered along with task related situational factors.

As was discussed earlier, within-subject experiments might elicit more comparative strategies in evaluations or decisions. Participants in between-subject designs have usually little basis for comparing options or potential rewards, since they are only confronted with one problem of a kind. Perhaps, administering the monetary deals for evaluations in a between-subject experiment would bring different results than ours. This distinction is essentially nothing but pointing out the importance to account for situational factors while interpreting experimental results.

Indeed, even natural judgment and choice situations may differ in a similar way as within- and between-subject experiments. Imagine a public policy that determines the proportion of value paid by an employer to the actual wage received by an employee. Such policy described in terms of gains could be: "proportion of the value that the employee will receive," or described as a loss: "value of the whole amount paid by the employer, which will be lost". Presenting these two descriptions to different samples in an evaluation task, for example in a public opinion poll, might result in frame affected evaluations. However, if a person, who is faced with this policy in a context of policies in other countries (e.g. a future employer planning a business) might employ more comparative strategy. Situational differences can have a profound effect on judgment in real world situations, just like in experimental ones. Framed information, despite being identical, can be processed differently in various contexts.

Effects of task modifications are also present within our experiment. In evaluations, the responses were not significantly affected by framing, however, once participants were to decide whether to accept or reject the same deals, they seemed to prefer gain framed ones to the loss framed. Despite this effect being rather small, it indicates that this inconsistency of responses, indeed, follows the pattern of framing effect. Even if it was a result of failings to recalculate the outcome information to the objectively received reward in a process of following a chosen decision policy, it would suggest that the errors in calculations tended to result in underestimating the rewards rather than overestimating them. This might indicate a genuine effect of framing, possibly related to affective states elicited by negative formulation.

Generally observed framing effects in acceptance rates of ambiguous outcomes suggest more positive expectations regarding gain framed ambiguity as compared to loss framed. In our contexts of ambiguous outcomes, it would be more than bold to claim they were equal descriptions of the same possible outcomes. Participants' beliefs about the possible values of outcomes associated with positive and negative frames could have differed significantly. This might be the case in outcomes with known magnitudes, however, when the objective outcome is known and is believed to be different from objectively equal differently framed one, it is defensible that this belief is irrational. In the case of ambiguous outcomes, such a normative criterion is inapplicable.

It can be speculated that framing effect in ambiguity might be a result of processes related to framing effect examined in known outcomes. Processing of ambiguous loss framed outcomes could have elicited more negative associations than the gain framed ones. Since no other basis for evaluation was really accessible, such signal might have more profound influence on behavior due to a lack of other sources of information available for processing. When outcomes are known, the value processing might be just parallel to another processing similar to the one which occurs with ambiguous outcomes. This additional signal would then contribute to evaluation to some degree. If

it is so and our results are any indication, the effect of value knowledge is rather high, since a very small framing effect was associated with unambiguous outcomes.

Descriptions were shown to have significant effect on response times. This observation might support the proposition that negative affect caused by negative description promotes engaging more cognitive effort (Kuo et al., 2009).

Interestingly, none of the behaviorally observed framing effects in tendency to accept outcomes or in reaction times were contingent on FRN differences. This suggests that processing associated with behavioral responses in framing tasks might be independent from FRN responses. Framing condition most significantly affected behavioral responses to ambiguous outcomes. What remains questionable is the amount of processing related exclusively to ambiguous outcomes and irrelevant to known ones. The possibility that framing effects observed in ambiguous situation are not too much related to those that give raise to framing in known outcomes cannot yet be dismissed.

Observation that framing had no similar effect on FRN as objective gains and losses usually do, suggests that this level and strand of processing might not be always affected by a description. At this point, however, it is important to note that in most of the previous experiments on framing effect, participants are faced with hypothetical scenarios and do not usually experience outcomes. Indeed, an experiment which investigated attribute framing on evaluation of meat, showed that describing meat as 20% fat or 80% lean had smaller effect, when participants had an opportunity to really taste it after being provided with a description (Levin & Gaeth, 1988). In the present experiment, participants experienced the outcomes repeatedly, which might have soon led to a realization that all the outcomes are positive and affected processing of following outcomes. This awareness might mitigate the affective distress caused by framed loss. Nevertheless, knowing that outcomes are always objective gains seems not to have been sufficient for processing ambiguous outcomes as positive rewards.

Absence of a unifying framing effect theory that would link all our observations together is one of the reasons why this research was undertaken, while remaining its explanatory framework limitation. Attribute framing is a simpler phenomenon more susceptible to experimental manipulation. Combination with low level valence processing indicator of such as FRN might be helpful in development of a more detailed cognitive account of attribute framing and possibly by extension risky choice framing effects. More theoretical synthesis might be beneficial to guide future research in postulating hypothesis grounded in lower level cognitive processing.

Prospect theory has limited association with the present research. Apart from describing evaluation specific for choice, which may be dissociated from single option evaluation (e.g. Hsee, Zhang, Yu, & Xi, 2003), it also makes predictions about decision utility, which is temporally prior to the experienced utility investigated in most parts of the present research. Despite that similar S-shaped function was recently described in function of experienced utility (Carter & McBride, 2013), assuming the same reference point manipulation effects is theoretically ungrounded at the moment. Therefore, possible implications of a research addressing low level processing, such as FRN in an attribute framing evaluation task, for prospect theory are very limited. Nevertheless, valence of experienced utility indexed by FRN seems not to be affected by description manipulation in a way the prospect theory would predict for decision utility.

The most profound limit of the present experiment is lack of comparison between clearly positive and negative outcomes. Neutral outcomes in the "all or nothing" part were expected to provide us with such comparative assessment; nevertheless, likely failure to elicit expected processing in this part deprived us of this determination. The lack of FRN effects in one part of our experiment calls for a degree of skepticism regarding the potential of our experimental design to investigate FRN. The proposed differences in the task processing described in the section 3.2.3. are rather speculative and the only observed FRN effects were related to a research question, without prior predictions. The effects were present on the Fz electrodes and to a slightly lower degree

on the Cz, as would be expected for FRN (Holroyd et al., 2004). However, the lack of evidence of similar effects to objectively neutral outcomes, which were expected to produce FRN in our context, reduces validity of the claim that our stimuli were suitable to isolate impact of framing on this ERP component.

In FRN experiments, simple stimuli, such as "+", "-", "0", usually indicate the outcome valence, while in our case the feedback stimuli contained a word and a number. Both valence and magnitude information was, to our knowledge, used in only the experiment addressing framing effect (Ma et al., 2012). More complicated stimulus could have added more noise to the outcome processing as compared to simpler one, by processes unrelated to the FRN, thus making these effects harder to isolate. Therefore, despite that our number of trials per condition should have been sufficient for a stable FRN (Marco-Pallares et al., 2010), increased complexity of our stimuli could have influenced the power of our experiment to measure FRN. Using simpler stimuli would be advisable for future research. However, the trade-off between similarity of stimulus to those previously used in framing effect research and the simplicity needed to reliably evoke desired cognitive processing necessary for ERP investigation is, indeed, a challenging issue.

4.1. Summary

In the context of our experimental task, favorability evaluations of risky and certain deals were unaffected by framing. The lack of framing effects might be indicative of some differences between gambles and Asian disease problem in regard to information equality of framed outcomes. However, various task-related aspects of framed outcome processing, such as repeated exposure to both frames and evaluation strategies possibly induced in within-subject experiments, need to be considered when comparing results between various experiments.

Apart from behavioral responses, FRN showed no effects of framing as well. We conclude that part of our experiment addressing "all or nothing" context failed to induce processing adequate for FRN response assessment. In the "always something" part, however, FRN effects associated with ambiguous outcomes were found. Despite concerns about our design's ability to detect FRN, the observed negativity might indicate an unexpectedly robust effect of ambiguity on affective and motivational processing. Interestingly, framing effect consistent responses were elicited by ambiguous outcomes, while the FRN was essentially equal. Assuming reliability of our ERP measures, this co-occurrence suggests that behavioral framing effects can result from processes unrelated to FRN.

Conclusions

Framing does not necessarily influence evaluations of favorability. However, it is important to consider the context of judgment. Just like in every-day situations, experimental setting can have a profound influence on how information is being processed. Thorough consideration of these factors might be more relevant now, than before, when more within-subject designs are being employed in investigations of the framing effect in fMRI, EEG or even eye-tracking studies. Most of the previous research was conducted on between-subject basis and processes that give raise to framing effect consistent behavior may differ significantly.

Present research suggests it might not too likely that manipulating description of an outcome valence results in processing analogous to objective gains and losses indexed by FRN. Furthermore, framing effect consistent responses can be dissociated from FRN differences. Both these observations should be addressed in future research, if the relation between FRN and framing effect is to be understood.

Despite that some evidence indicating neurophysiological correlates of framing has emerged in the last decade, it suffers from theoretical exploratory limitations and lack of replication. A number of experimental manipulations are proposed in present discussions that could help to investigate FRN as one of the possible sources of processing related to framing effect in a more detailed manner.

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