Neurofinance: Exploratory Analysis of Stock Trader's Decision-Making Process by Real-Time Monitoring of Emotional Reactions

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Abstract: Human emotions can be associated with decision-making, and emotions can generate behaviors. Due to the fact that it could be biased and exhaustively complex to examine how human beings make choices, it is necessary to consider relevant groups of study, such as stock traders and non-traders in finance. This work aims to analyze the connection between emotions and the decision-making process of investors and non-investors submitted to the same set of stimuli to understand how emotional arousal might dictate the decision process. Neuroscience monitoring tools such as Real-Time Facial Expression Analysis (AFFDEX), Eye-Tracking, and Galvanic Skin Response (GSR) were adopted to monitor the related experiments of this paper and its accompanying analysis process. Thirty-seven participants attended the study, 24 were classified as stock traders, and 13 were non-traders; the mean age for the groups was 35 and 25, respectively. The designed experiment initially disclosed a thought-provoking result between the two groups under the certainty and risk-seeking prospect theory; there were more risk-takers among non-investors at 75%, while investors were inclined toward certainty at 79.17%. The implication could be that the non-investing individuals were less complex in thought and therefore pursued higher returns besides a high probability of losing the game. In addition, the automatic emotion classification system indicates that when non-investors confronted a stock trending chart beyond their acquaintance or knowledge, they were psychologically exposed to fear, anger, sadness, and surprise. On the contrary, investors were detected with disgust, joy, contempt, engagement, sadness, and surprise, where sadness and surprise overlapped in both parties. Under time pressure conditions, 54.05% of investors or non-investors tend to make decisions after the peak(s) of emotional arousal. Variations were found in the deciding points of the slopes: 2.70% were decided right after the peak(s), 37.84% waited until the emotions turned stable, and 13.51% were determined as the emotional indicators started to slide downwards. Several combinations of emotional responses were associated with decisions. For example, negative emotions could induce passive decision-making, in this case, to sell the stock; nevertheless, it was also examined that as the slope slipped downwards to a particular horizontal point, the individuals became more optimistic and selected the "BUY" option. Future works may consider expanding the study to larger sample size, different demographic groups, and other biometrics for further analysis and conclusions.

Keywords: Neuroscience, Decision-making, Emotions, Behaviour, Physiological, Investors

1. Introduction

People believe that we make countless choices of free will daily. Is it a fact? Philosophers contain various views on free will, biologically and metaphysically. In simple terms, free will defines the ability or discretion to choose. Free will therefore does not adequately explain why we act as we do (Kolb and Whishaw, 2014). We may think that the most obvious explanation for our behavior is simply that we want to. The description assumes that we act in a state of free will- that we always have a choice (Kolb and Whishaw, 2014). Nevertheless, within the scope of science, free will is a vague term and does not explicitly clarify how choices are made.

Humans are born with freedom of choice, yet, the determinant behind the scene makes investigating decision-making critical and fascinating to expand the study further to identify the potential influencers and how the outcomes would differ. Hence, this research aims to fill the gap by identifying and evaluating how emotional responses affect investors' and non-investors' decisions and how stimuli may link with emotional arousal via integrating multi-modal neuroscience-based tools.

People often confront choices that could be either fearful, life-changing, or life-threatening, making it essential to discover what is guiding the process of judgment-making capacity. Although logic plays a role, much of decision-making is driven by emotion (Gordon and Arian, 2001). Many empirical studies since the 1970s revealed the domination of emotions involves judgments and decisions under diverse psychological aspects rendering people's perception, especially under a particular state of how one feels, namely, joy, anger, anxiety, fear, disgust, and sadness (Lerner *et al.*, 2015). Therefore, emotions can determine either means, sometimes beneficial or harmful drivers of decision-making.

1.1 Research Question

The previous discussions lead us to define the research question:

- *Question*: To what extent does active monitoring of stimuli reactions attempt to deepen our understanding of the investors' and non-investors' decision-making process based on emotions?

To answer the question, the experiment sequence, questionnaire, and content must be logical and acknowledgeable by the readers, accompanied by a reasonable time limit to obtain the expected effects. Creating a time gap or break time between each sub-design frame was vital to capture respondents' instant reactions to the corresponding setting and prevent perplexing emotional outcomes.

2. Methodology

Our research aim is to reveal the process of decision-making in connection with emotions which plays a vital role in human behavior. Emotion can dictate behavior that utterly influences one's decision outcomes. Yet, the veracity of choices shall not be the scope of discussion in the study. We, in turn, focus on the transition of emotions through external factors or impacts. This thesis emphasizes our study from the stock traders' perspective. The research also collected data from non-traders to allow comparative analyses. Multiple non-intrusive physiological techniques were applied to respondents to explore and examine the probable development of emotions in decision-making.

2.1 Research Design

This work is experimental research in which, according to Skinner (1966), the task of empirical analysis is to explore all the variables of which the probability of response is a function. By conducting the study, we can have firm control over variables to obtain results; more significantly, our collected data could be utilized to build new research ideas for further studies due to the limitation of sample size in the Macao, China region.

2.1.1 Experiment model

The research adopted qualitative and quantitative analysis based on data collected through a self-report questionnaire, a computer-assisted survey, and a short video with a series of questions. The questionnaire and the survey were designed to understand participants' demographic characteristics for further data analysis. The survey and a short video followed after the participants completed the questionnaire. Additionally, the video aimed to experiment with respondents' feedback on an acute laboratory stressor. In reality, traders frequently encounter time pressure and involve time-constraint judgment while executing trading decisions. Therefore, the experimentation was required to incorporate scenarios to monitor emotional responses regarding choice under certainty, risk reflection effect, emotional arousal, time pressure, and emotional manipulation. With the support of a biofeedback monitoring system, the experimental structure made it possible to examine the reactions between traders versus non-traders and their attitudes to decision-making while confronting external impacts. The experiment was tailored to monitor the responses, potential emotional migration, and their related decision-making process while fronting virtuous and poor options and stress. Participants were informed to answer a few questions by selecting the answers they assumed were most feasible to their belief displayed in the video. The experimental questions contain individuals assessing loss and gaining perspective with time pressure, stimuli, and stimuli manipulation.

2.1.2 Research sample

Participants comprised 23 women and 14 men (n = 37) aged 18 to 72. Seven respondents were English illiterate; thus, Mandarine's version of the experiment material was arranged, and the others were presented with an English version. Among the respondents, 24 were identified as stock or index or futures traders, and 13 were identified as non-traders. The mean age for investors and non-investors was 35 and 25, respectively.

The scope of the experiment aimed to study the decision-making process in connection with the emotional reactions and their alterations of humans. In his publication of Human Emotions, Izard stated that emotions tend to affect all aspects of each individual, the whole person (Izard, 2013). The point of departure is then the position that we are essentially organisms of a particular animal species, namely homo sapiens, so that the locus of mental life that we reidentify when we reidentify a person over time is just an instance of a biological kind, a kind whose members typically exhibit complex mental life (Johnston, 1987). Even though every being is born with distinct characteristics, the fundamental cognitive and perception scheme is innate, along with measures of emotional impacts and contrasting decision outcomes. Thus, the number of participants shall be deemed plausible to demonstrate a representative fraction of the beings.

2.1.3 Experiment design

The experiment consists of four phases: initially presented with the choice options under certainty and risk; the second, third, and fourth parts aimed at monitoring participants' trading decisions and their real-time emotional reactions (AFFDEX) together with eye-tracker and Galvanic Skin Response (GSR) monitoring.

Figure 1 demonstrates the roadmap of the experiment by employing the below circumstances:

1. Decision-Making and process under certainty (from the prospect theory)
2. Decision-Making and process under risk (from the prospect theory)
3. Decision-Making and emotions through the unacquainted information
4. Decision-Making and emotions under time strain
5. Decision-Making process under emotional manipulation

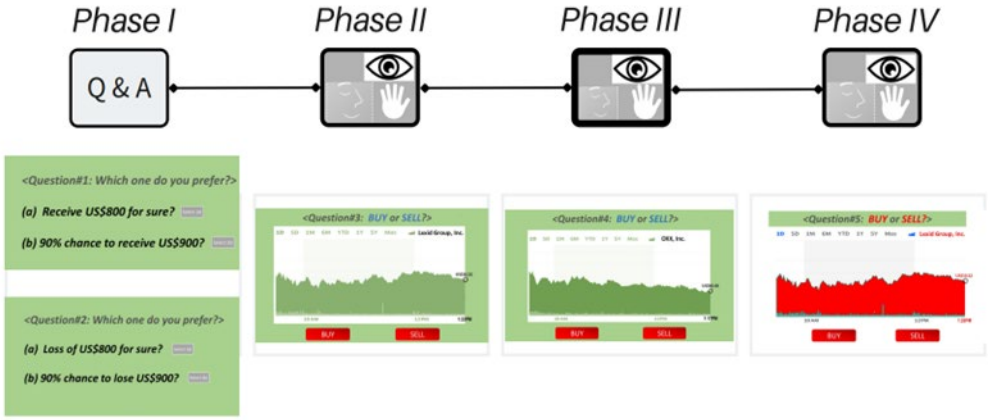

Figure 1: Experiment Roadmap including Four Phases. The Monitoring Tools: Eye-tracking, AFFDEX, and GSR

Phase I depicted two questions, as presented in Figure 2, about risk-averse versus risk-seeking; each question is set to a ten-second time limit. According to Kahneman (2011), humans opt for certainty and dislike risks; however, when facing poor choices, they are inclined to transform into risk-seeking. Therefore, in this phase, we proposed the results would lead to the same outcomes as the theories based on the respondent's responses.

Question #1:	***Which do you prefer?***
(a) Receive US$800 for sure?	
(b) 90% chance to receive US$900?	
Question #2:	***Which do you prefer?***
(a) Loss of US$800 for sure?	
(b) 90% chance to lose US$900?	

Figure 2: Illustration of Risk-Averse and Risk-Seeking (Kahneman, 2011)

As demonstrated in Figure 1, *phases II* (Question #3) and *III* (Question #4) each contained one stock trading chart, and the time duration between both steps was designed with a 5-second variation to create time pressure; the former phase was a 10-second chart, while the latter was 5 seconds. In this stage, the first presumptions were to acquire more significant emotional reactions from non-investors due to their unacquainted with investing activities. The second strategy was implementing the time contrast as a stimulus to monitor the vibrant dissimilarities among investors and non-investors. Besides, emotional arousals such as anxiety, irritation, fear, and frustration were significantly expected.

Phase IV (Question #5) implemented the identical chart as Phase II with the same timeframe of 10 seconds. Nonetheless, the trending color was modified to red to explore if the specific alteration in the theme color would be a factor of emotional stimuli of excitement. In addition, we further expected to verify if this color alteration would arouse more active purchasing intention, and we anticipated the majority of the participants would have the impulse to hit the buy button. Red can be associated with excitement, considered an arousing and stimulating color (Crowley, 1993).

3. Results and Discussion

Data evaluations and the demonstration of the results acquired from the experiment were based on the four phases of the investigation of the experiment.

3.1 About Respondents

The final sum of participants is 37 (*n = 37*), ranging from 18 to 72 years (*M = 34, SD = 14*). The distribution between investors and non-investors was 24 (64.86%) and 13 (35.14%). Among all the attendees, 5.41% (n=2) were Western, and the others were all Asian; the distribution of male and female was 38% (n=14) and 62% (n=23), with a total of 7 (18.92%) participants being English illiterate. The experiments were conducted from March 3, 2023, through March 24, 2023.

3.2 Phase I – Prospect Theory – Questions #1 & #2

Prospect theory (Kahneman, 2011) explicitly addresses that humans are advocates when confronting circumstances under certainty and being risk-takers when facing relatively poor options.

Among the 24 investors, 79.17% preferred assurance when an option of certainty was available, against 62.50% who were more risk-taking, where all the possibilities appeared to be unwanted. The result on the investors' side undoubtedly supports the theory in that most people act to match the view. On the contrary, a reversal result was found in non-investors, where 50% opted for certainty, and 75.00% were risk-taking. Figure 3 below demonstrates the variation obtained between the two groups.

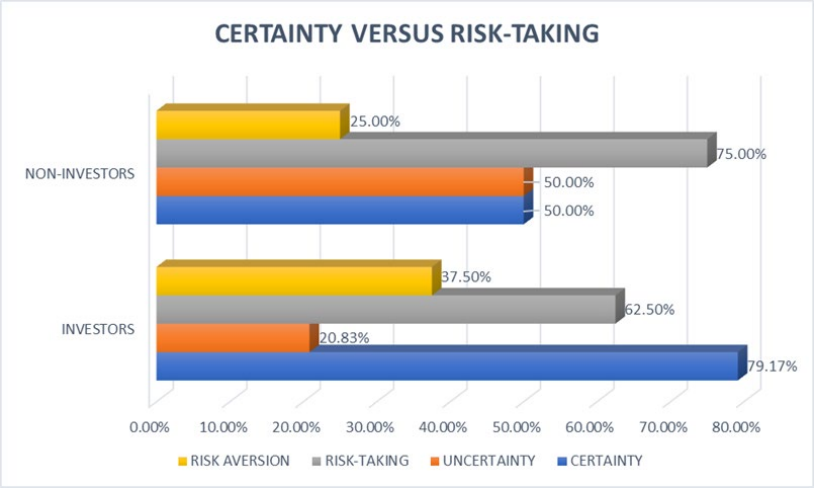

Figure 3: Variations of Non-Investors & Investors' Choices Between Certainty & Risk-Taking

Nevertheless, observing the outcome from a different approach in a greater dimension showed that people who opted for certainty were not necessarily adventuresome. One possibility for the variation in investors could be that a certain percentage of people believe "losing less is gaining" and walk away with what is already in their pocket. They do not believe taking a higher risk to obtain a probability of loss is essential, even if the dollar amount is sufficiently attractive.

Another finding further revealed that the non-investors could be the braver risk-seekers as they could have uncomplicated mindsets. The questions could catch their authentic thoughts off-guard, unlike investors who are frequently convinced they are more sophisticated in investing activities; hence, they tend to produce far more complex thoughts than others.

3.3 Results for Emotional Arousal – GSR Monitoring

Since skin conductance is not under human conscious control, sweat gland activity increases and increases skin conductance once the emotion is highly aroused. Peak occurrences reveal if any peaks can be identified throughout the experiment.

3.3.1 Peak occurrences

Figure 4.13 represents the experiment's peak occurrences of investors and non-investors from the Survey stage through Phase IV. 29.17% (n=17) of investors detected no peaks, while 29.17% (n=7) detected peaks. On the contrary, positive peak occurrences in non-investors amounted to 46.15% (n=6) and 53.85% (n=7) without peak

occurrences. The group of non-investors demonstrated a higher percentage of peak occurrences of 46.15% than the investors' 29.17%.

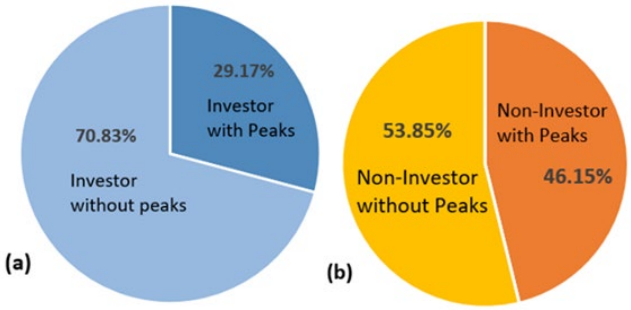

Figure 4: (a) Peak Occurences on Investors (b) Peak Occurrences on Non-Investors

Table 1: Investor Peak Occurrences by Stimuli

Stimuli	Investors with Peaks (n)	Investors with Peaks (%)	Investors with no Peaks (n)	Investors with no Peaks (%)
Survey	7	29.17%	17	70.83%
Q1: Decision-Making under Certainty	4	16.67%	20	83.33%
Q2: Decision-Making under Risk-Taking	4	16.67%	20	83.33%
Q3: Emotions & Decision-Making under Unacquainted Content	6	25.00%	18	75.00%
Q4: Emotions & Decision-Making under Time Pressure	3	12.50%	21	87.50%
Q5: Emotions & Decision-Making under Different Color Scenes	4	16.67%	20	83.33%
Note: total n = 24				

Table 2: Non-Investor Peak Occurrences by Stimuli

Stimuli	Non-Investors with Peaks (n)	Non-Investors with Peaks (%)	Non-Investors with no Peaks (n)	Non-Investors with no Peaks (%)
Survey	5	38.46%	8	61.54%
Q1: Decision-Making under Certainty	3	23.08%	10	76.92%
Q2: Decision-Making under Risk-Taking	4	30.77%	9	69.23%
Q3: Emotions & Decision-Making under Unacquainted Content	4	30.77%	9	69.23%
Q4: Emotions & Decision-Making under Time Pressure	1	7.69%	12	92.31%
Q5: Emotions & Decision-Making under Different Color Scenes	2	15.38%	11	84.62%
Note: total n = 13				

Tables 1 and 2 represent both groups' comprehensive peak occurrences analysis by stimuli with the number of respondents with peaks.

The peak occurrences comparison by stimuli amongst two groups is demonstrated in Figure 5. The result shows that a higher percentage of peak detections were captured on non-investors during the experiment, except in Q4 and Q5: decision-making under time pressure and in different color scenes. Investors revealed a slightly higher peak percentile in decision-making under time pressure and decision-making under different color scenes, with variations of 4.81% and 1.29% from non-investors, respectively. A weightier variation of 14.1% between the two groups can be located in Q2: decision-making under risk in which non-investors were exposed to more peaks. The outcomes were less significant on the remaining questions, with less than a 10% difference for each stimulus.

According to Figure 5, it is probable to presume that non-investors were more vulnerable to generating a higher probability of peaks in terms of their state of emotions initiated from the survey section through Q3. Nonetheless, investors were exposed to higher peaks of 12.50% under Q4: decision-making under time pressure, suggesting that the respondents in this group were experiencing higher emotional elevations than non-investors at 7.69%.

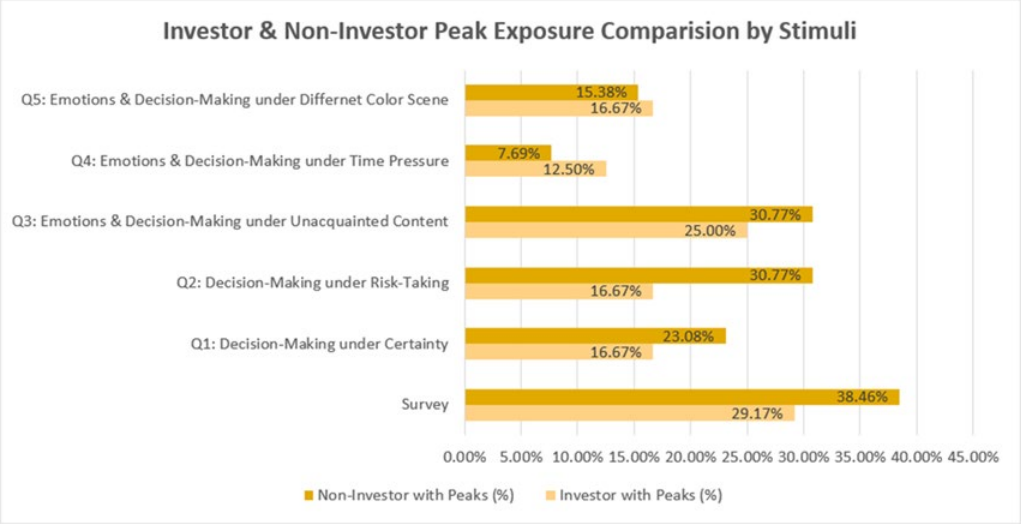

Figure 5: Investor & Non-Investor Peak Occurrences Comparision by Stimuli in Percentage

3.4 Results for Emotions Detection - AFFDEX

With the integration of AFFDEX, it can capture facial expressions and translate them into seven emotions: joy, surprise, anger, fear, sadness, disgust, and contempt. The facial expression analysis was adopted to examine participants' emotional states under four phases of stimuli. According to Ekman and Cordaro (2011), these primary emotions are a set of stimuli that have influenced beings for tens of thousands of generations. In the meanwhile, the facial expression analysis also incorporates the detection of engagement as well as attention.

The mechanism of affirming an emotion under the analysis originates from the 30 consecutive emotional frames per second as a threshold, that is, the duration of the threshold of 30ms. Hence, the results were accounted for when greater than or equal to a duration threshold of 30ms.

Figure 6 represents the percentile of the seven emotions among the investors. It is readily observable that the emotion of fear dominated a higher percentage during the entire experiment, ranging from 53.3% to 79.1%. Fear (53.3%) and surprise (31.26) were expressed in the survey section. Under the decision under certainty, fear (69.64%) occupied the highest percentile, accompanied by minor sadness (14.00%). It is also worth noting that the prevalence of emotions such as fear and joy occurred with comparable share under two stimuli: decision under risk-taking and decision under time pressure, at 51.42% versus 32.93% and 58.15% versus 36.52%, respectively, although the fear and joy increased by 6.73% and 3.59% under decision under time pressure. Investors were also exposed to greater fear (57.47%) while viewing the stock trending chart in the decision under unacquainted content, coexisting with minor sadness (18.58%) as well as joy (14.37). Finally, the group demonstrated exceptionally higher fear in the decision under the color framing section 79.17%; here, we observed a 21.70% increase in fear to 79.17% compared with Phase II, decision under unacquainted content.

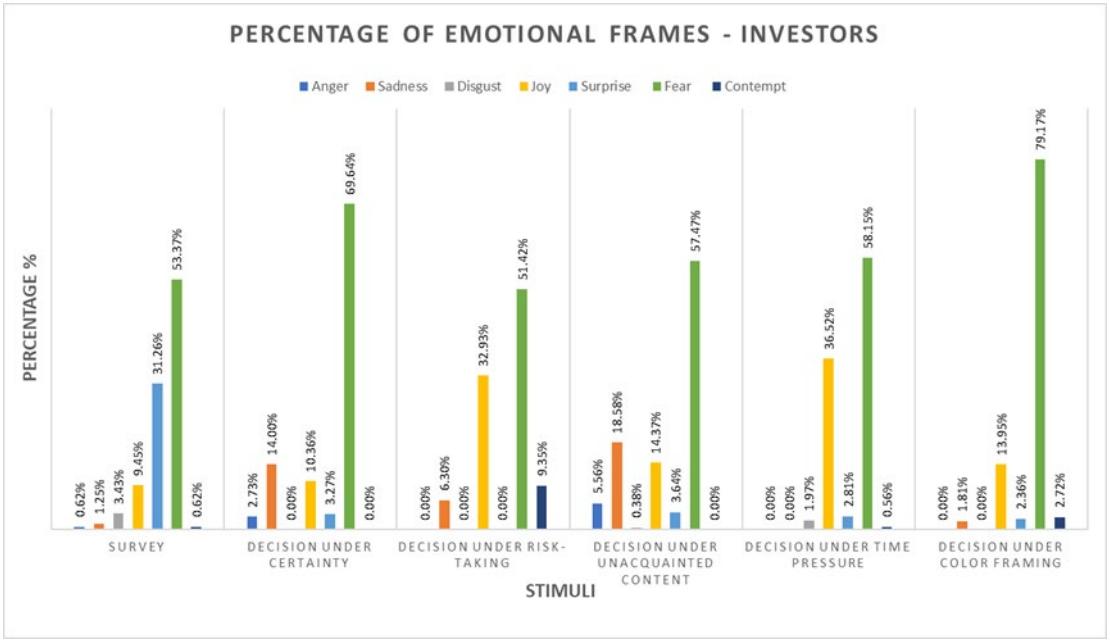

Figure 6: Percentage of Emotional Frames Detected from Investors During the Experiment (>=30ms)

Figure 7 illustrates the emotional scale of the non-investor throughout the experiment. In contrast to investors, the non-investors group revealed a higher percentile of sadness (36.64%~75.93%) and surprise (49.79%~64.58%) during the experiment. The group was exposed to a relatively large scale of surprise (49.79%) and fear (46.44%) while taking the survey. Sadness occupied 50.00% of the decision under certainty, with fear at 27.72%. Moreover, sadness surged by 20.14% to 71.14% in the decision under risk-taking. Sadness remained dominated the decision under unacquainted content at 36.64%. With the stimulus of decision under time pressure applied, the emotions migrated to surprise (64.58%) and fear (28.13%). Lastly, in the decision under color framing, sadness is observed to increase in this group by 39.29% to 75.93% compared with the decision under unacquainted content.

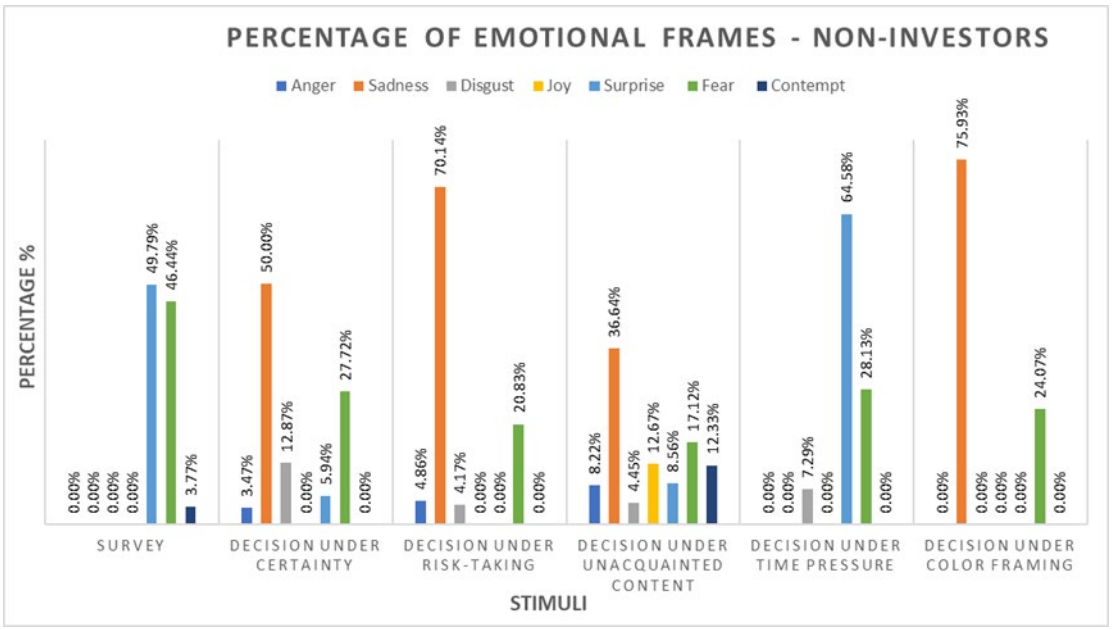

Figure 7: Percentage of Emotional Frames Detected from Non-Investors During the Experiment (>=30ms)

3.5 Summary

In *phase I (Q1 and Q2)*, non-traders were captured with more significant peak exposures than the other group. The result coincided with Figure 7, that the non-trader group initiated relatively intense sadness in this phase. From a qualitative angle, non-traders demonstrated risk-seeking while facing poor choices (see Figure 3). The result suggests that high exposure to sadness could link to the risk-taking choice.

Phase II (Q3) was architected to monitor mainly non-traders responses due to their unfamiliarity with the trading activities. Moderate sadness (36.64%) was captured but accompanied by multiple emotional reactions, such as anger, joy, surprise, fear, and contempt. The outcome may imply when non-investors confront unfamiliarity, they tend to display mixed feelings. In the qualitative aspects, Table 3 illustrates the result obtained from this phase, revealing that the shared emotions of both groups are "surprise" and "sadness." Additionally, investors commonly demonstrated "joy," "disgust," "contempt," and "engagement," while "fear" and "anger" frequently arose in the opposite group.

Table 3: Emotions Obtained from Phase II – Investor V.S. Non-investors

	(Overlapped Emotions)					
INVESTORS	*Surprise*	*Sadness*	Joy	Disgust	Contempt	Engagement
NON-INVESTORS	*Surprise*	*Sadness*	Fear	Anger		

Phase III (Q4) obtained a minimal peak occurrence under GSR (see Tables 1 and 2). At the same time, a higher percentage of fear and surprise were exposed to investors and non-investors, respectively (see Figures 6 and 7). Based on the outcome, it can be concluded that both groups face time stress varied in emotional reactions.

Lastly, the results of *Phase IV (Q5)* become a focus of discussions in this research; it would be challenging to conclude why both groups displayed a significant growth of the exact emotion in *Phase II (Q3) and Phase IV (Q5)* with the manipulation of background coloring. Figure 8 represents the result of a positive correlation with the exact emotions of both groups.

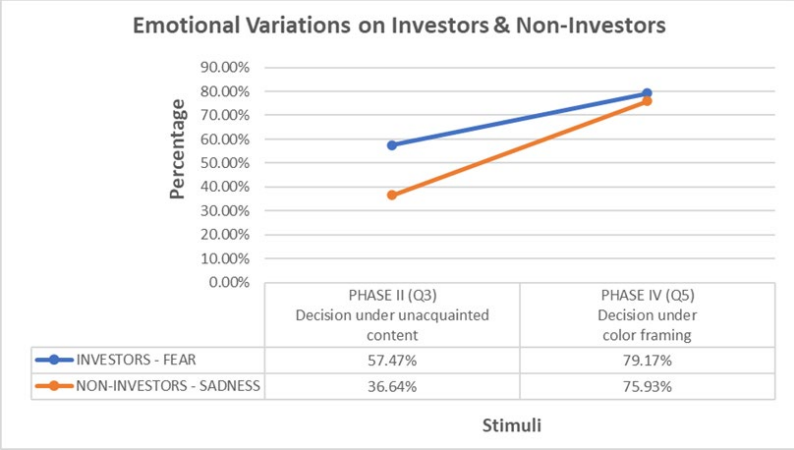

Figure 8: Emotional Variations on Phase II and IV between Investors & Non-Investors

4. Conclusion

This research suggests that human nature can be unpredictable with the complexity of emotions and decisions. However, it is achievable by segregating by groups or characteristics and then systematically reviewing their associated choices and responses to discover the factors. It is now possible to conclude that an active monitoring system can deepen our understanding of emotions from different angles and their potential impacts on decisions; meanwhile, the system also facilitates examining the deciding policy procedures. The study allowed us to disclose the variances between the groups and the complexity of human emotions.

5. Limitations and Future Research

The study has potential limitations, and it is recommended to increase the demographic populations with multiple regions, various races, a more significant sample size, a full range of emotions, and a long-term assessment of emotional effects. Besides, future research can consider expanding the experiment time to obtain sustainable responses from the GSR tool and with applications of a significant impact of anxiety to create a substantial difference in the experiment. Electroencephalogram (EEG) can further validate the decision-making process and cross-reference with the results from the AFFDEX in the qualitative perspective. The virtual experiment could also be considered; nonetheless, the current GSR would not be applicable. With artificial

intelligence technology evolving, we will hopefully overcome the present obstacles to achieve a more applicable virtual experiment environment to benefit researchers.

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