

UNIVERSITY OF OREGON

# Beauty Contest: K-Level Thinking

by

Aijie Zhao

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Approved By:

Advisor: Jaibin Wu



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# *Abstract*

Economics

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This paper experimentally examines human behavior in a real “Beauty Contest” and tries to understand what drives people to make specific choices . This “Beauty Contest: K-LEVEL Thinking Study” is a web-based experiment with 5 treatments, and over 600 data points were collected. Is John Maynard Keynes's conjecture on human behavior based on beauty contest valid in the experiment? Our results provide a positive answer.

## *Acknowledgements*

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To my dearest parents Xueqing Jiao and Jinliang Zhao: I always thinking how lucky I am to have parents like you. You like the sun, warm me up, give me energy, and light up the whole sky.

Thanks to Yixing Tian, I will miss our interesting and long-lasting chat. Thanks for your kindness and patience.

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# Chapter 1

## Introduction

John Maynard Keynes used a beauty contest to compare the behavior of rational agents in the stock market.

“...professional investment may be likened to those newspaper competitions in which the competitors have to pick out the six prettiest faces from a hundred photographs, the prize being awarded to the competitor whose choice most nearly corresponds to the average preferences of the competitors as a whole; so that each

competitor has to pick, not those faces which he himself finds prettiest, but those which he thinks likeliest to catch the fancy of the other competitors, all of whom are looking at the problem from the same point of view. It is not a case of choosing those which, to the best of one's judgment, are really the prettiest, nor even those which average opinions genuinely thinks the prettiest. We have reached the third degree where we devote our intelligences to anticipating what average opinion expects the average opinion to be. And there are some, I believe, who practice the fourth, fifth and higher degrees.” (John Maynard Keynes, *General Theory of Employment, Interest and Money*, 1936, p. 156).

He believes that, in the stock market, people to price stocks is not based on what their fundamental value is, but instead choose what they think average opinion thinks the fundamental value is or even based on what they think average opinion expects the average opinion thinks the fundamental value is.

## **1.1 Background and Literature Review**

Rosemarie Nagel became known for the Beauty Contest experiment. She writes: "I learned about the guessing game in a game-theory class given by Roger Guesnerie,

who used the game as a demonstration experiment." (Nagel, 1995, p. 1313). Beauty Contest experiment was called guessing game initially. In Beauty Contest experiment, participants were asked to guess a number between 0 and 100, the number that closest to a share  $p$  ( $p=1/2, 2/3$  or  $4/3$ ) of the average is the winning number. In this instance, a level-0 player chooses randomly as usual; a level-1 player would assume every other player is a level-0 player, and the average to be around 50, leading them to choose  $50*p$  as their number; a level-2 player would assume every other player is a level-2 player, then their best choice is  $50*p*p$  as their number; one can define any level- $k$  player in the same fashion, which is referred to as K-level thinking model. Inspired by Nagel's reference (Nagel, 1995) to Keynes' (1936, p. 156) comparison of newspaper beauty contest and stock market investments, Ho, Camerer, and Weigelt (1996, 1998) were the first to call this guessing game "p-Beauty Contest." (Christoph Bühren, Björn Frank and Rosemarie Nagel, 2012).

## **1.2 Motivation**

We live in a world that people do not behave what to remain the status stable; people have different levels of strategic sophistication hence behave heterogeneously. This news released recently: "On June 6th, the Dongguan Public Resource Trading Network released the "End Quote Rules after the online transaction of Dongguan



Land Resources reached the upper limit”. The rules showed that after the online quotation reached the upper limit, the trading system suspended accepting new quotes and switched to online. The final one-off quotation method (from now on referred to as “final quotation”) determines the bidding method of the winning candidate by the principle of the closest quotation in the final quotation, and the price quoted is identified as the final quotation of the parcel. For example, if there are 5 housing companies participating in the final quotation, which are quoted at 1 billion, 1.3 billion, 1.4 billion, 1.5 billion, and 1.6 billion respectively, the average is 1.36 billion yuan, and the bidding company with a price of 1.4 billion yuan is the closest. The average price of the final offer, the plot is won by the company.”. This is a “Beauty Contest” in real life.

This study aims to understand human behavior in a real “Beauty Contest” and some variants of it. Many studies have been conducted on a digital version of the “Beauty Contest”, however, to our limited knowledge, little has been done on the “Beauty Contest” initially proposed by Keynes, and we plan to actualize it. This “Beauty Contest: K-LEVEL Thinking Study” is a web-based experiment designed to improve our understanding of what humans thinking levels are in the real “Beauty Contest”, and what drives people to make specific choices by changing a single variable in each treatment.

# Chapter 2

## Experimental Design

This Chapter will first outline the overview of the experiment and summarize the five treatments involved. All participants participate in this experiment through Wechat, and their decisions are submitted anonymously. By posting e-posters on Wechat Moment and using sharing functions in mini-programs, we recruited our participants.

### 2.1 Overview

We programmed a WeChat mini-program which allows us to implement the experiment and collect data on Wechat, the most popular social media App in China, and we used its own view languages named WXML and WXSS, as well as a JavaScript-based logical layer. This experiment consisted of 5 treatments, and each treatment consisted of two to three phases. In the first phase of each treatment, participants will start the first-round voting by choosing the most attractive picture they believe from the six pictures are given. Once subjects submitted their choices,

they will start the second-round voting. In the second-round voting, the participants whose choice of the pictures matches the requirement of the winning picture of the second-round voting will get the chance to win a prize of 100 RMB yuan (Random draw from participants who choose the most popular picture).

## **2.2 Treatments**

**Treatment 1 (T1):** The same six pictures (From now on, we call the first picture P1, the second picture P2, and so on.) in both phases. The picture with the highest number of votes in the second-round voting is the winning picture. The following is a more detailed explanation of the process:

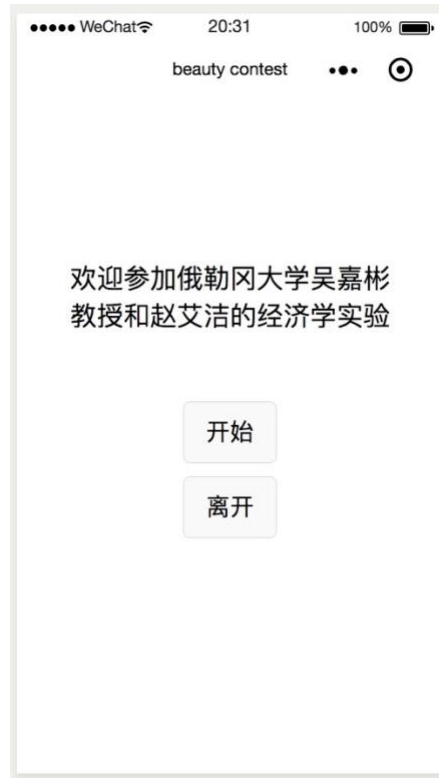


Figure I (page 1): After participants open the mini-program, they will see a welcome page: “Welcome to participate our Economic Experiments”, and there are two buttons follow: the first one is “start” and the second one is “leave”.

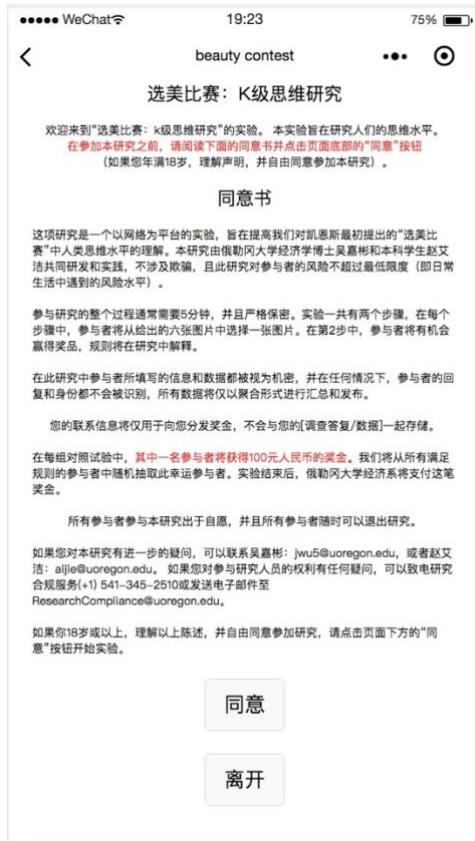


Figure II (page 2): After participants click “start” button in the first page, the consent will be presented on page 2. (Consent form see attachment) There are two buttons on the bottom: the first one is “agree” and the second one is “leave”. Participants must click “agree” button to go to next step.

The image shows a mobile application interface for a survey. At the top, the status bar displays 'WeChat', the time '20:33', and '100%' battery. Below the status bar, there is a navigation bar with a back arrow, the title 'beauty contest', and a circular icon. The main content area contains the following fields and options:

- 联系方式 (email/微信号) :
- 年龄:
- 来自省份:
- 性别:  
 男  女  其他

At the bottom of the form, there are two buttons: '开始' (Start) and '离开' (Leave).

Figure III (page 3): Participants will fill out a survey: “How can we contact you? What is your age? Which province are you from? What is your gender?”. Participants must fill all the questions and click “start” button to continue the experiment, or they can leave by click “leave” button.



Figure IV (page 4): Now the participants will start the first-round voting by choosing the most attractive picture they believe from the six pictures are given, and click “submit” button to go to the second-round voting.



Figure V (page 5): After participants submit their first-round voting, they will start the second-round voting. In the second-round voting, the participants whose choice of picture (from the same six pictures in the first step) matches the winning picture of the second-round voting will get the chance to win a prize of 100 RMB yuan (Random draw from participants who choose the most popular picture).





Figure VI (page 6): The last page—thanks for the participate. Participants could share the program to others by click the yellow button on the top.

**Treatment 2 (T2):** Same as T1 except before second-round voting, the participants are shown a data chart that shows the data of second-round voting of T1.

**Treatment 3 (T3):** Same as T2 except in the second-round voting, the picture with the second highest number of votes is the winning picture. After the second-round voting, participants need to submit a statement of the reasons for their choices.

**Treatment 4 (T4):** Same as T1 except one of the six pictures is changed to a picture of a famous star instead. After the second-round voting, participants need to submit a statement of the reason for their choices.

**Treatment 5 (T5):** Same as T1 except all six pictures are changed to pictures of famous stars.

## **2.3 Hypotheses**

Based on the theory of level-k thinking, we propose the following hypotheses for the outcomes of the 5 treatments.

**Hypothesis 1:** We believe the higher thinking level players will choose the picture which they think the average opinions thinks the prettiest instead of choosing the picture which those participants themselves think the prettiest. Therefore, in T1, the hypotheses for the outcome is part of the participants will make inconsistent choices across the two rounds of voting.

**Hypothesis 2:** In T2, by giving the participants the result of the second-round voting of T1, the participants who change their votes to the winning picture of T1 will increase significantly in the second-round voting, since the higher thinking level players will receive useful information that which picture is the average opinions thinks the prettiest.

**Hypothesis 3:** In T3, in the second-round voting, different levels of thinking will occur, and the winning picture might be changed. In the second-round voting of T3, level 0 players with non-strategic play at random; level 1 players play the best respond to level 0, which is to choose the picture with the second highest number of votes in the second-round voting in T1; level 2 players play the best respond to level 1, which is to choose the picture with the highest number of votes in the second-round voting in T1; level 3 players play the best respond to Level 2, which is to

choose the same picture that level 1 players will choose. If the proportion of the level 0 players is the largest, then level 1 players and level 3 players will be the winners. If the proportion of the level 1 players is the largest, then level 2 players will be the winners.

**Hypothesis 4:** In T4, the famous star provides useful information for the higher thinking level players, and instead to choose the picture that they think the prettiest, they will tend to choose the picture of the star. We believe the picture of the famous star will have the highest growth rate of the number of votes across the two rounds voting.

**Hypothesis 5:** In T5, we believe the higher thinking level participants will make their decision in the second-round voting based on their knowledge of which star is the most popular one, instead of choosing the picture which they think the prettiest. Therefore, part of participants will make inconsistent choices in the two rounds voting. The picture with the highest number of votes in two rounds of voting might be different.

## **Chapter 3**

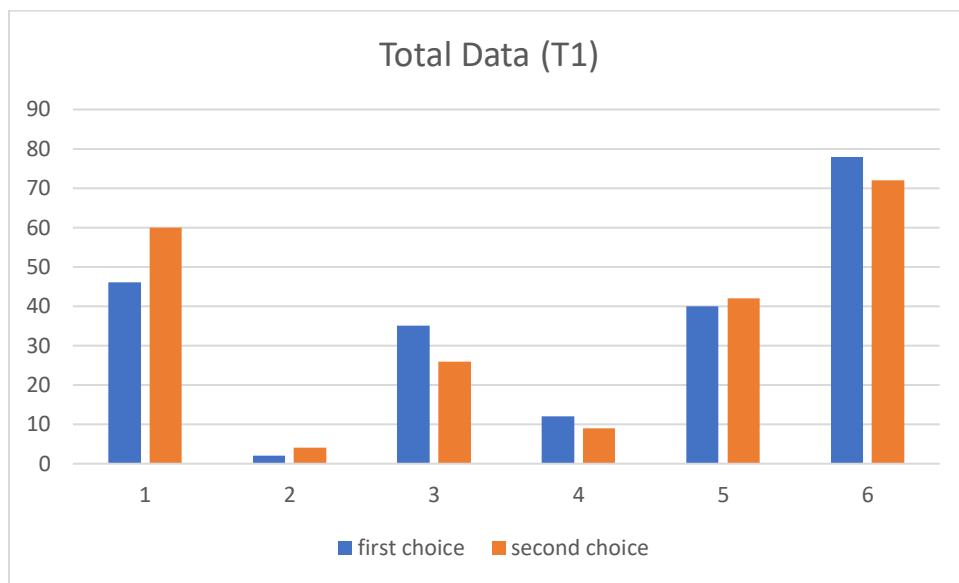
### **Results**

In this chapter, the summary statistics of the experiment will be reported by each treatment.

### 3.1 T1

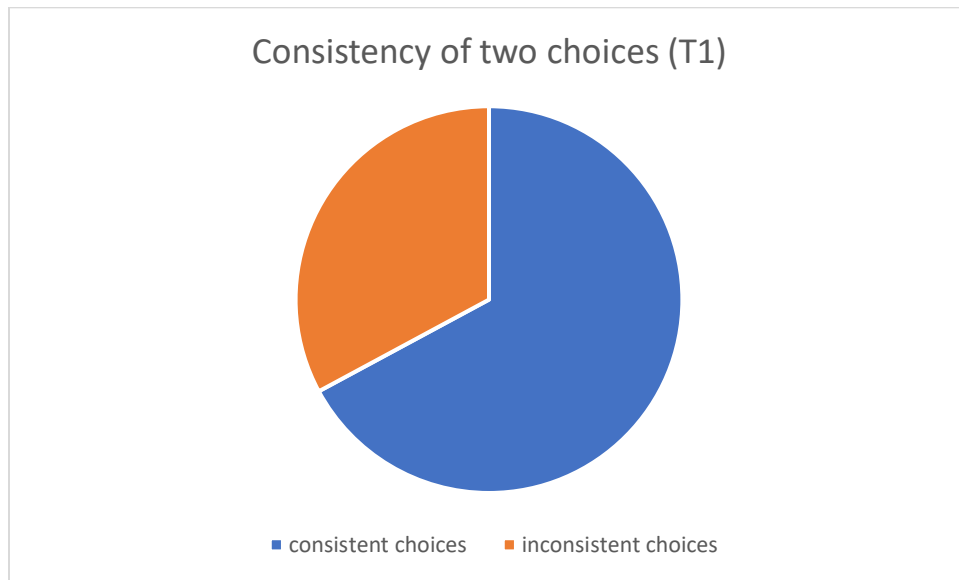
Recall Treatment 1 (T1): The same six pictures in both phases. The picture with the highest number of votes in the second-round voting is the winning picture.

Figure 1 shows the number of votes cast in two rounds per picture in T1.



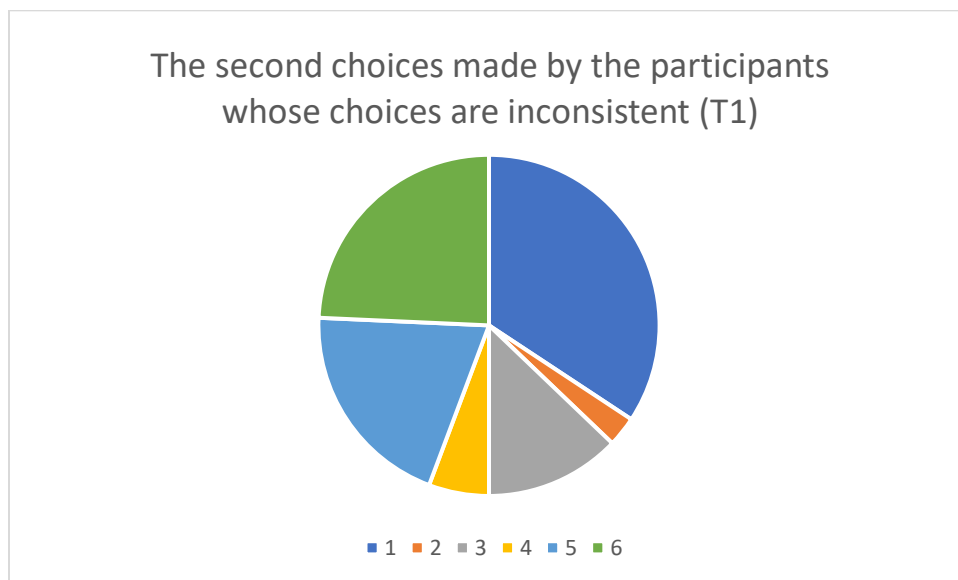
**Figure 1.** Number of votes per picture (T1)

Figure 2 shows the proportion of the consistency of voting in the two rounds voting in T1. In this treatment, 33% of objects voted different pictures in the two rounds voting, and 77% objects voted the same picture.



**Figure 2.** Proportion of consistency of two choices (T1)

Figure 3 shows the proportion of the second choices made by the objects whose choices are inconsistent in the two-round voting in T1. 34% of the participants whose choices are inconsistent in the two rounds voting in T1 changed their votes to P1, 3% changed their votes to P2, 13% changed their votes to P3, 6% changed their votes to P4, 20% changed their votes to P5 and 24% changed their votes to P6.



**Figure 3.** Proportion of the second choices made by the participants whose choices are inconsistent (T1)



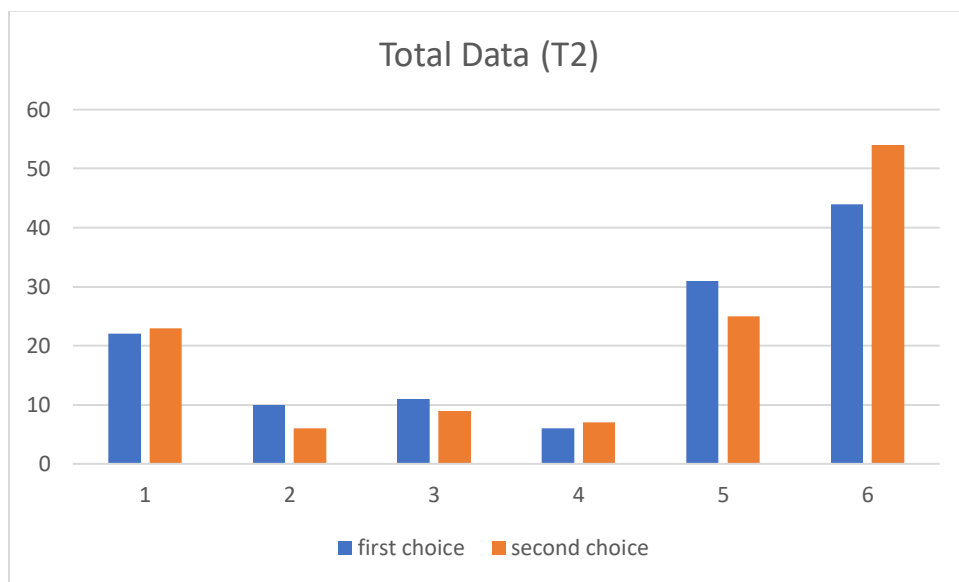
In T1, P6 has the highest number of votes in both rounds voting, and it is the winning picture. In Figure 3, P1 and P6 are the top two pictures that participants changed their votes to, but in Figure 1, the number of votes of P6 decreased from the first-round voting to the second-round voting.

In T1, 33% of the participants made inconsistent choices across the two rounds of voting. Including the participants who made the consistent choices across the two rounds of voting that believe the picture they choose is the average opinions thinks the prettiest, more than 33% of participants in this treatment have higher thinking level than level 0.

## 3.2 T2

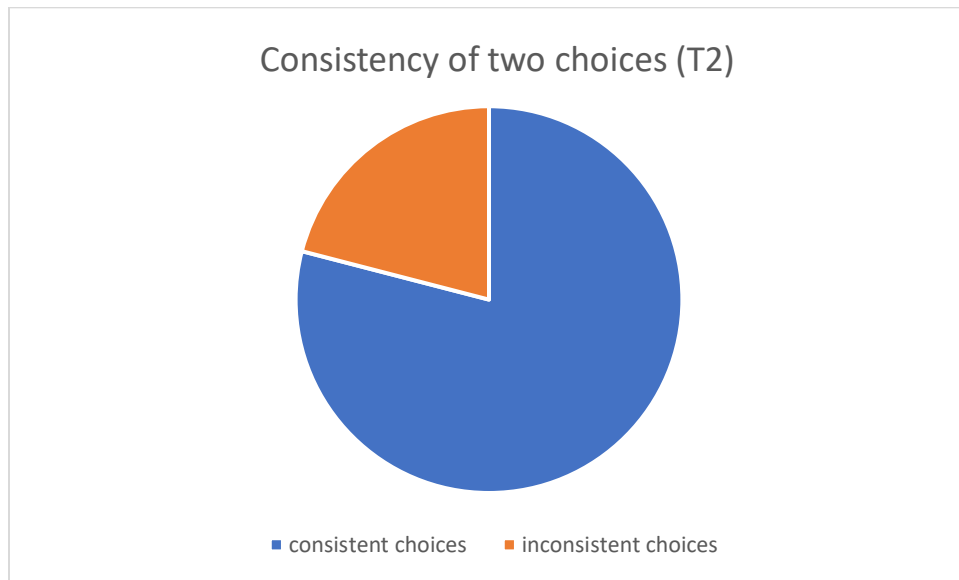
Recall Treatment 2 (T2): Same as T1 except before second-round voting, the participants are shown a data chart that shows the data of second-round voting of T1.

Figure 4 shows the number of votes cast in two rounds per picture in T2.



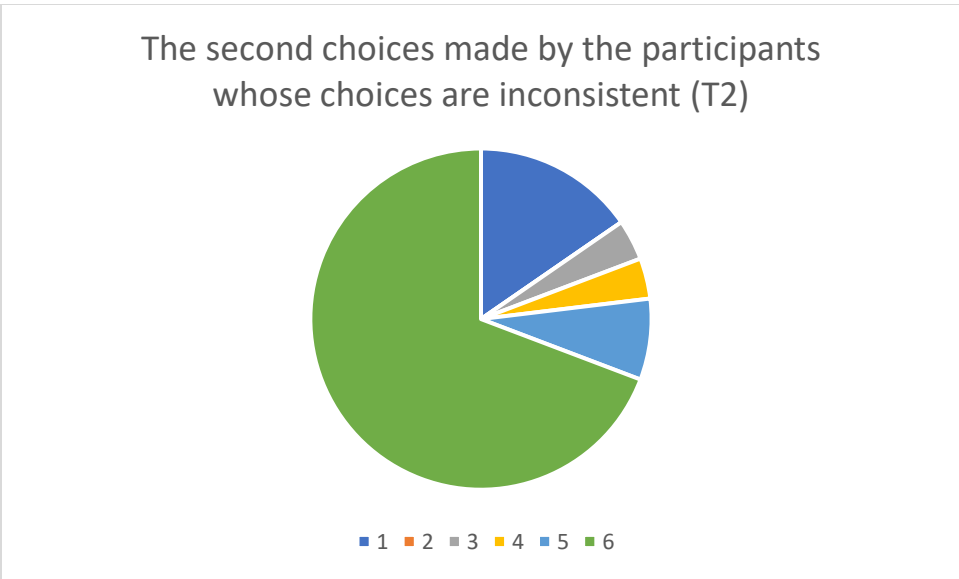
**Figure 4.** Number of votes per picture (T2)

Figure 5 shows the proportion of the consistency of voting in the two rounds voting in T2. In this treatment, 21% of objects voted different pictures in the two rounds voting, and 79% objects voted the same picture.



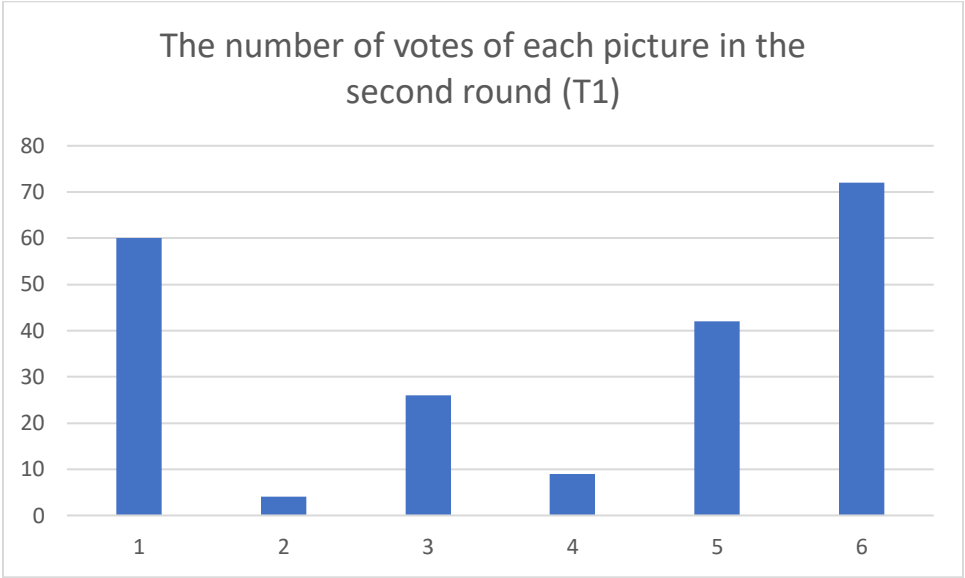
**Figure 5.** Proportion of consistency of two choices (T2)

Figure 6 shows the proportion of the second choices made by the objects whose choices are inconsistent in the two-round voting in T2. 15% of the participants whose choices are inconsistent in the two rounds voting in T2 changed their votes to P1, 0% changed their votes to P2, 4% changed their votes to P3, 4% changed their votes to P4, 8% changed their votes to P5 and 69% changed their votes to P6.



**Figure 6.** Proportion of the second choices made by the participants whose choices are inconsistent (T2)

Before second-round voting participants are shown a data chart that shows the number of votes of each picture in the second-round voting of T1, which is Figure 7, reflects the information that P6 was the winning picture in T1.



**Figure 7.** The number of votes of each picture in the second round (T1)

In T2, P6 has the highest number of votes in both rounds voting, and it is the winning picture. Compare Figure 6 and Figure 3, the proportion of the participants whose choices are inconsistent in the two rounds voting changed their votes to P6 increased

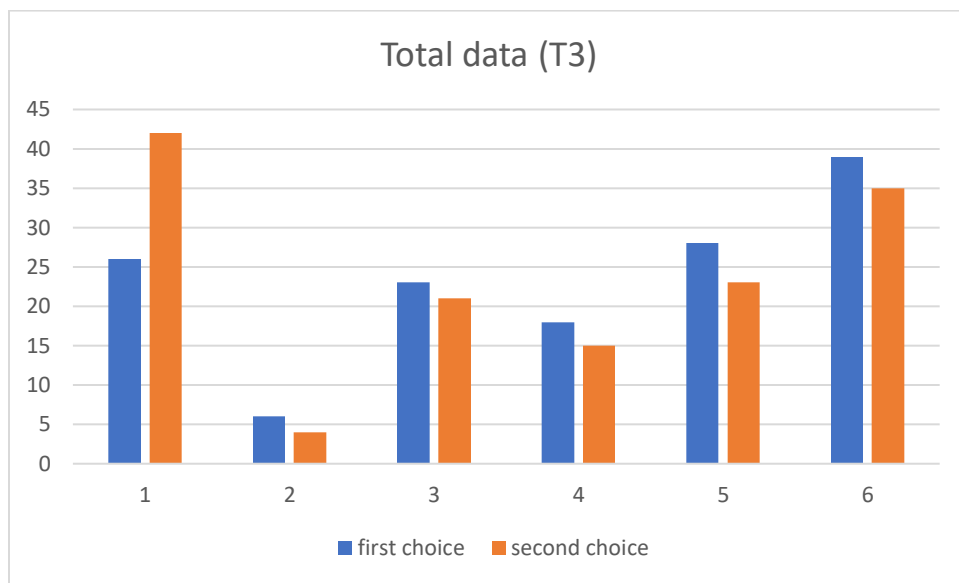
from 24% (T1) to 69% (T2).

In T2, by giving the participants the result of the second-round voting of T1, the proportion of the participants who changed their votes to the winning picture in T1 in the second-round voting increased significantly. We believe the reason for this result is because instead of letting the higher thinking level participants themselves analyze which picture is the average opinion thinks the prettiest, Figure 7 gave the participants the information that P6 is the average opinions genuinely thinks the prettiest. Based on this information, higher thinking level players tend to give their votes to P6 in the second-round voting.

### 3.3 T3

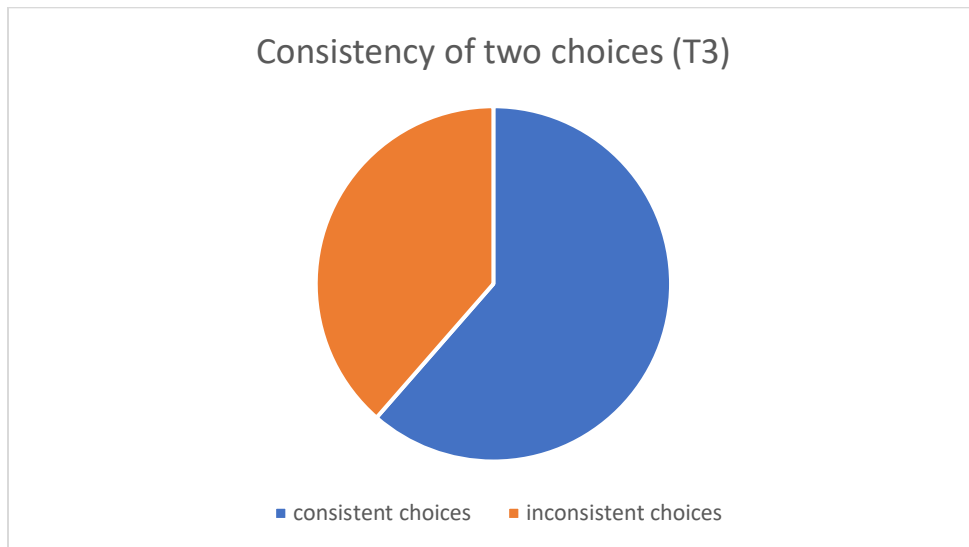
Recall Treatment 3 (T3): Same as T2 except in the second-round voting the picture with the second highest number of votes is the winning picture. After the second-round voting, participants need to submit a statement of the reason for their choices.

Figure 8 shows the number of votes cast in two rounds per picture in T3.



**Figure 8.** Number of votes per picture (T3)

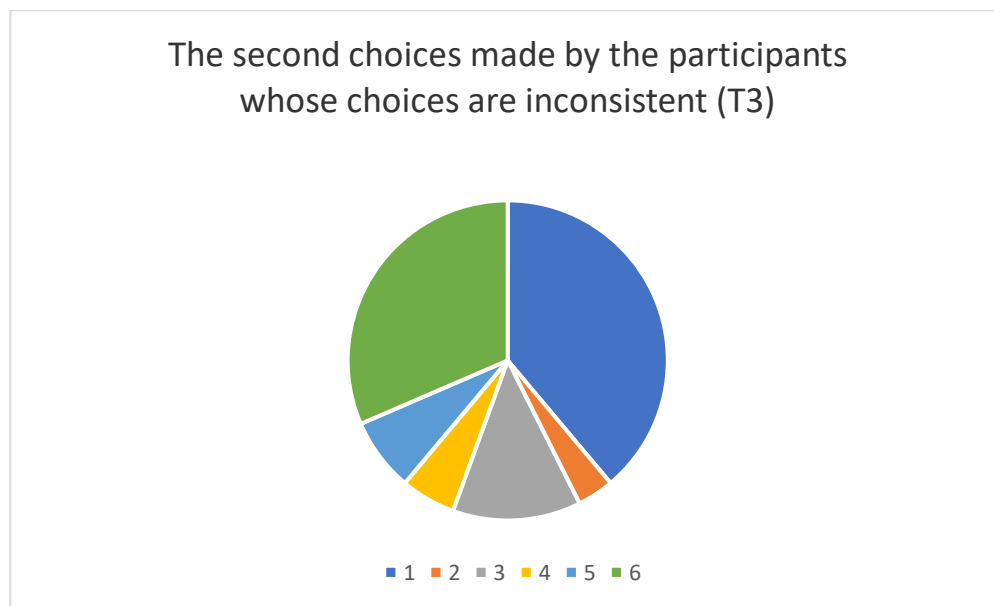
Figure 9 shows the proportion of the consistency of voting in the two rounds voting in T3. In this treatment, 39% of objects voted different pictures in the two rounds voting, and 61% objects voted the same picture.



**Figure 9.** Proportion of consistency of two choices (T3)



Figure 10 shows the proportion of the second choices made by the objects whose choices are inconsistent in the two-round voting in T3. 39% of the participants whose choices are inconsistent in the two rounds voting in T3 changed their votes to P1, 4% changed their votes to P2, 13% changed their votes to P3, 6% changed their votes to P4, 7% changed their votes to P5 and 31% changed their votes to P6.



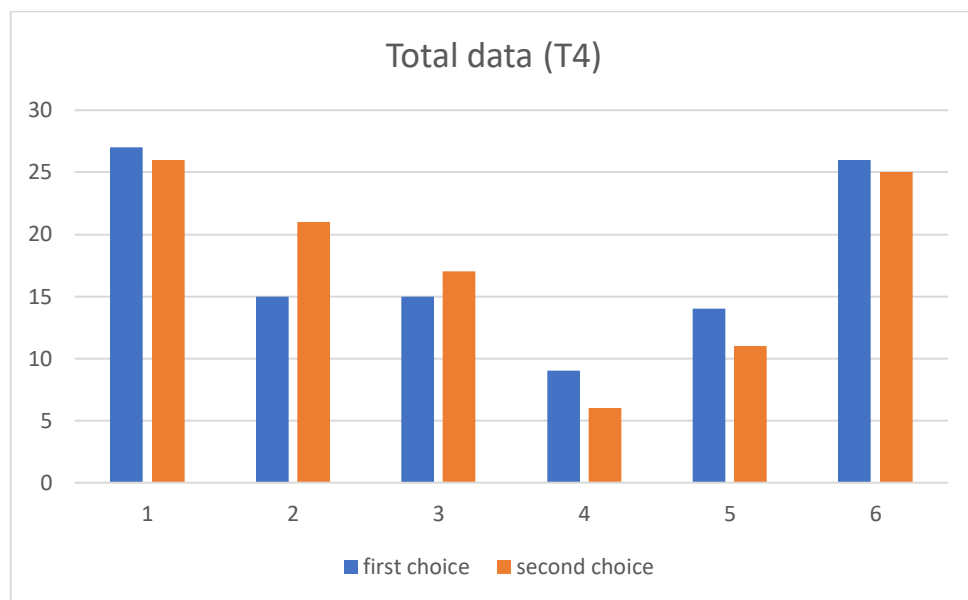
**Figure 10.** Proportion of the second choices made by the participants whose choices are inconsistent (T3)

In Figure 8, the first-round voting of T3 P6 has the highest number of votes. In the second-round voting of T3 P6 ends up with the second highest number of votes, and P1 has the highest number of votes. The winning picture in T3 is P6. Compare Figure 10 and Figure 3, the proportion of the participants whose choices are inconsistent changed their votes to P6 increased from 24% (T1) to 31% (T3), and to P1 increased from 35% (T1) to 39% (T3). In T3, level 0 players with non-strategic play at random; level 1 players play the best respond to level 0, and based on Figure 7, which is to choose P1; Level 2 players play the best respond to Level 1, which is to choose P6. Based on the Figures above and the accurate statements of the reason for the choices submitted by participants, Level 1 players account for the most significant proportion, followed by Level 2 players. There are only two Level 3 players play the best respond to Level 2, which is to choose P1. Even though there are participants who are level 3 players, their choice is the same as level 1 players' choice. Therefore, the level 2 player's choice is the best response of the second-round voting of T3. In this treatment, level 2 players are the winners.

### 3.4 T4

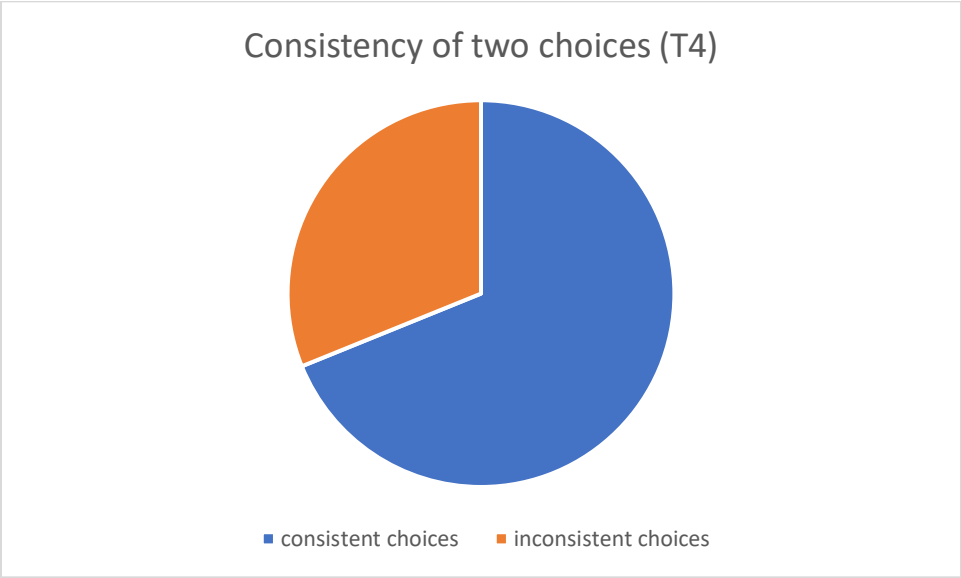
Recall Treatment 4 (T4): Same as T1 except P2 is changed to a picture of a famous star instead. After the second-round voting, participants need to submit a statement of the reason for their choices.

Figure 11 shows the number of votes cast in two rounds per picture in T4.



**Figure 11.** Number of votes per picture (T4)

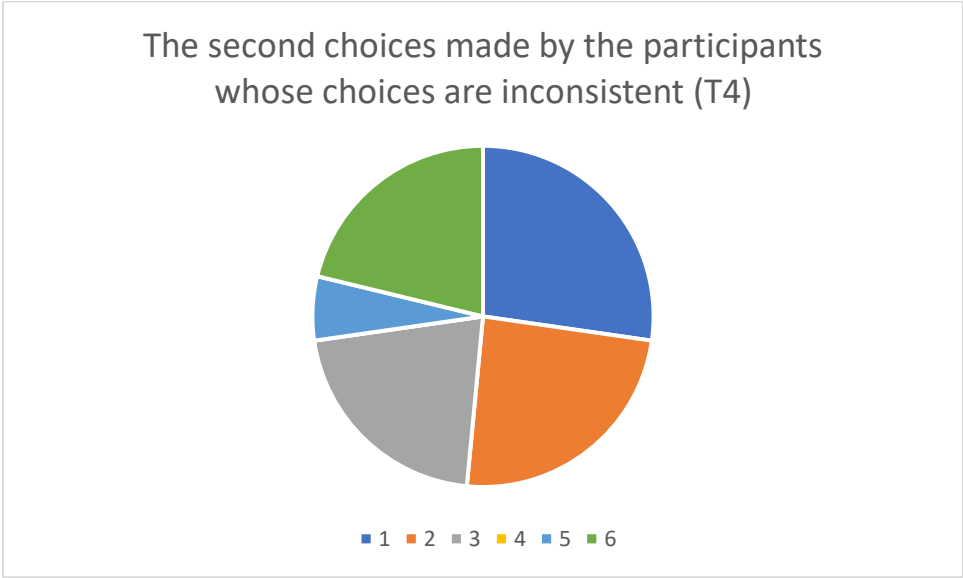
Figure 12 shows the proportion of the consistency of voting in the two rounds voting in T4. In this treatment, 31% of objects voted different pictures in the two rounds voting, and 69% objects voted the same picture.



**Figure 12.** Proportion of consistency of two choices (T4)

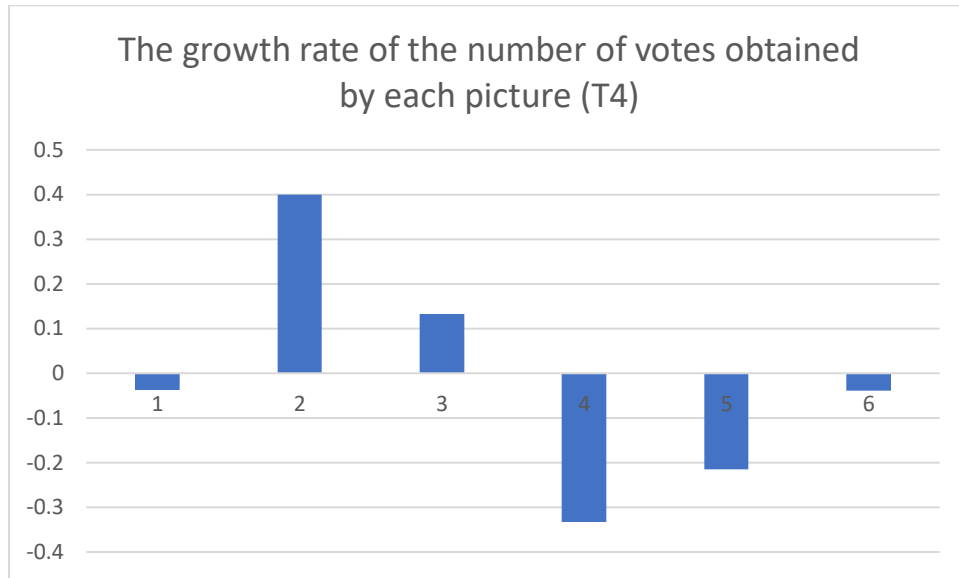
Figure 13 shows the proportion of the second choices made by the objects whose choices are inconsistent in the two-round voting in T4. 27% of the participants whose

choices are inconsistent in the two rounds voting in T4 changed their votes to P1, 24% changed their votes to P2, 21% changed their votes to P3, 0% changed their votes to P4, 6% changed their votes to P5 and 21% changed their votes to P6.



**Figure 13.** Proportion of the second choices made by the participants whose choices are inconsistent (T4)

Figure 14 shows the growth rate of the number of votes obtained by each picture from the first-round voting to the second-round voting in T4.



**Figure 14.** The growth rate of the number of votes obtained by each picture (T4)

In Figure 11, P6 has the highest number of votes in both rounds voting, and it is the winning picture. However, from Figure 14, P2 has the highest growth rate of the number of votes obtained from the first-round voting to the second-round voting in T4.

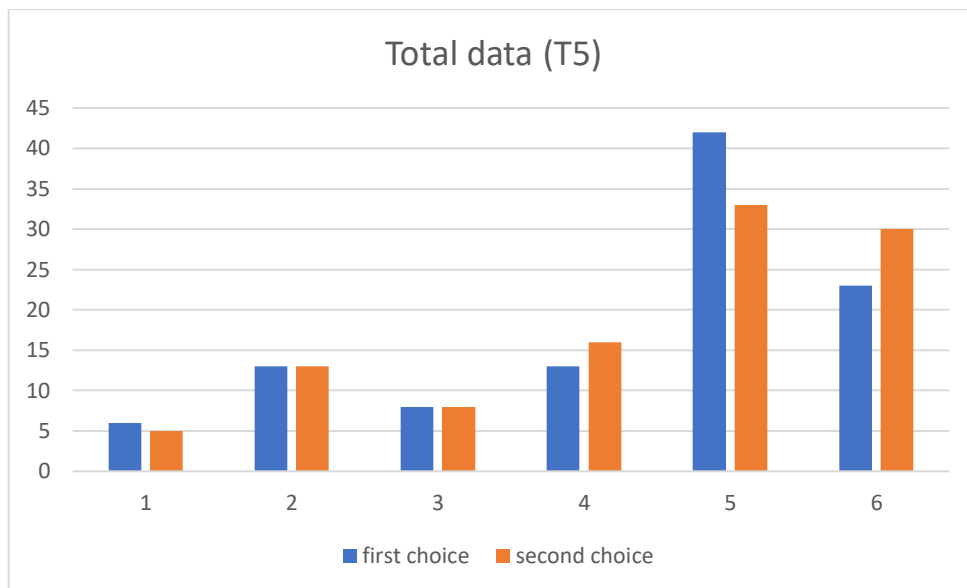
Based on the Figures above and the accurate statements of the reason for the choices submitted by participants, we observe the picture of the famous star is a focal point

in T4 since “because P2 is a picture of a famous star” is the most frequently repeated reason. The famous star provides useful information for the higher thinking level players who recognize P2 is a picture of a famous star, but it is ignored by most of the level-0 players who insist on their most preferable choices.

### 3.5 T5

Recall Treatment 5 (T5): Same as T1 except all six pictures are changed to pictures of famous stars instead.

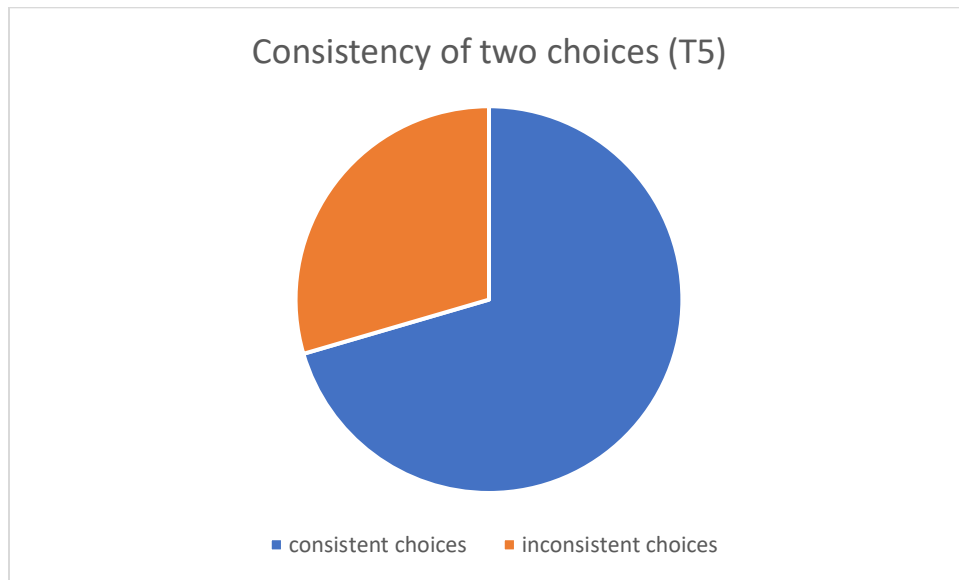
Figure 15 shows the number of votes cast in two rounds per picture in T5.



**Figure 15.** Number of votes per picture (T5)

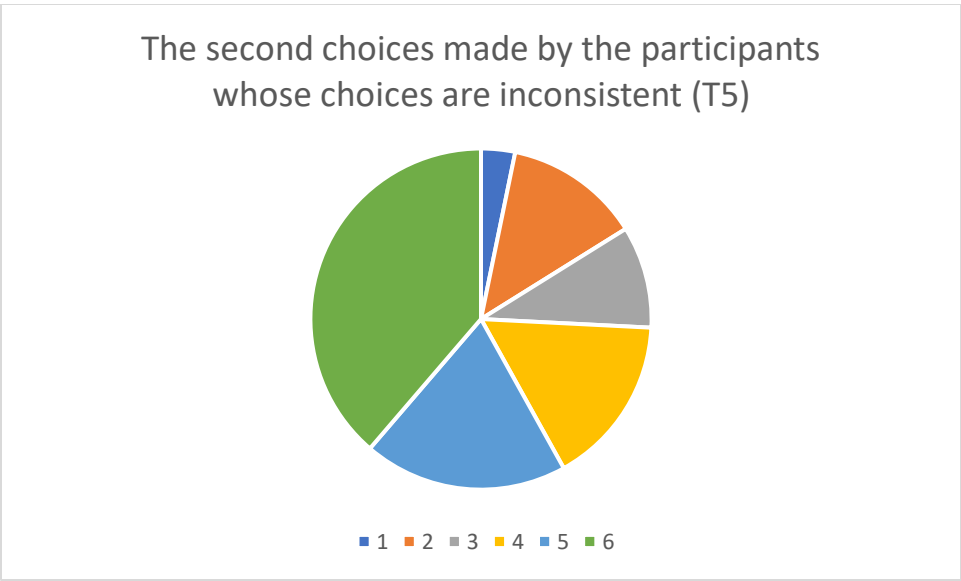


Figure 16 shows the proportion of the consistency of voting in the two rounds voting in T5. In this treatment, 30% of objects voted different pictures in the two rounds voting, and 70% objects voted the same picture.



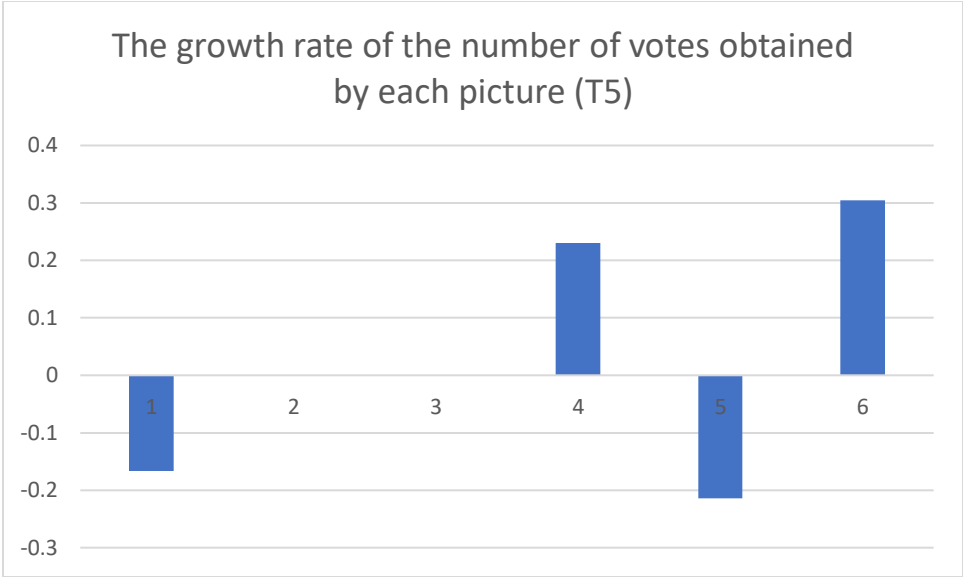
**Figure 16.** Proportion of consistency of two choices (T4)

Figure 17 shows the proportion of the second choices made by the objects whose choices are inconsistent in the two-round voting in T5. 3% of the participants whose choices are inconsistent in the two rounds voting in T5 changed their votes to P1, 13% changed their votes to P2, 10% changed their votes to P3, 16% changed their votes to P4, 19% changed their votes to P5 and 39% changed their votes to P6.



**Figure 17.** Proportion of the second choices made by the participants whose choices are inconsistent (T4)

Figure 18 shows the growth rate of the number of votes obtained by each picture from the first-round voting to the second-round voting in T5.



**Figure 18.** The growth rate of the number of votes obtained by each picture (T5)

In Figure 15, P5 has the highest number of votes in both rounds voting, and it is the winning picture. However, from Figure 18, P6 has the highest growth rate of the number of votes obtained from the first-round voting to the second-round voting in T4. Based on the Figures above and the accurate statements of the reason for the

choices submitted by participants, we observe P6 is a focal point in T5 since “Because the famous star in P6 graduated from the University of Oregon, and the participants in this experiment include many students from the University of Oregon.” is the most frequently repeated reason. Some other interesting reasons mentioned by the participants, such as “because the star in P2 is the icon of the most participants” and “because the star in the picture that I choose has the most fans”. From such statements, we observe the higher thinking level participants made their decision in the second-round voting based on their knowledge of which star is the most popular one, instead of choosing the picture which they think the prettiest.

# Chapter 4

## Conclusion

In this experiment, we observe the thinking levels for most people are less than level 3. When the picture with the second highest number of votes will be the winning picture, level 1 players account for the most significant proportion, therefore, level 2 players who play the best respond to level 1 thinking became the winners. In the treatment with a picture of a famous star, the famous star provides useful information for the higher thinking level players who recognize the star, and that picture is naturally became the focal point. When all six pictures are all famous stars, participants will start analyzing which star has the most fans, or more prominent, instead of determining which star is the best looking. In such games, although the players need to guess the thinking level of other players, the number of repeated reasoning steps used by human is limited, people do not need to regard others as completely rational. The experiment shows that the winner does not need to be completely rational, and that the most rational player is not necessarily the winner; the key to win is think one step more than others, but not more.

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