Internet Appendix for 'Exploring the Nature of "Trader Intuition"'*

The Internet Appendix consists of six parts. In the first part, we elaborate on the brain imaging experiment. The second part discusses the parametrization of the markets experiment. The third, fourth and fifth parts cover the instructions for the markets, imaging and behavioral experiments, respectively. The sixth part lists the questions on the mathematics section of the behavioral experiment, along with the correct answers.

The markets and brain imaging experiments were run at Caltech and were approved by Caltech's ethics committee. The behavioral experiments were run at Caltech and UCLA and were approved by the ethics committees of both institutions.

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Part 1. Brain Imaging Experiment

Experimental Design

We replayed the order and trade flow to 18 subjects while we recorded their brain activity. The subjects had not been in either the markets experiment or behavioral experiment.

First, we explained to the subjects how we had acquired the order and trade flow. We familiarized them with the markets experiment, showing the instructions that the subjects in that experiment were given, and how they would have traded. Second, we gave them instructions for the imaging experiment and asked them to sign a consent form. (The instructions are in Part 3 of this Internet Appendix.) We made sure that they understood the experiment by administering a quiz.

We reminded subjects that they would not be able to trade in the market after taking an initial position, and hence, that they would only act as observer of the replay of a previously recorded market. We also instructed them that the term "insider" did not refer to illegal "insider trading," but only to the fact that insiders had superior information.

We replayed the thirteen sessions of the original markets experiment in a different random order for each subject. Each session began with a "blind bet:" we asked subjects to choose between Stock X or Stock Z, after we informed them whether there were insiders. Subjects automatically took a position in 10 units of their chosen stock. Because of the perfect complementarity between payoffs on X and Z, taking a

position in 10 units of Z is equivalent to holding 10 notes and a short position in 10 units of X. After the subjects had made a choice, we replayed the order and trade flow for stock X, regardless of their choice, at double the speed (2 minutes and 30 seconds instead of 5 minutes). Finally, we displayed the dividend on the stock that they had chosen before the replay. The various steps for a single session are shown in Figure IA1.

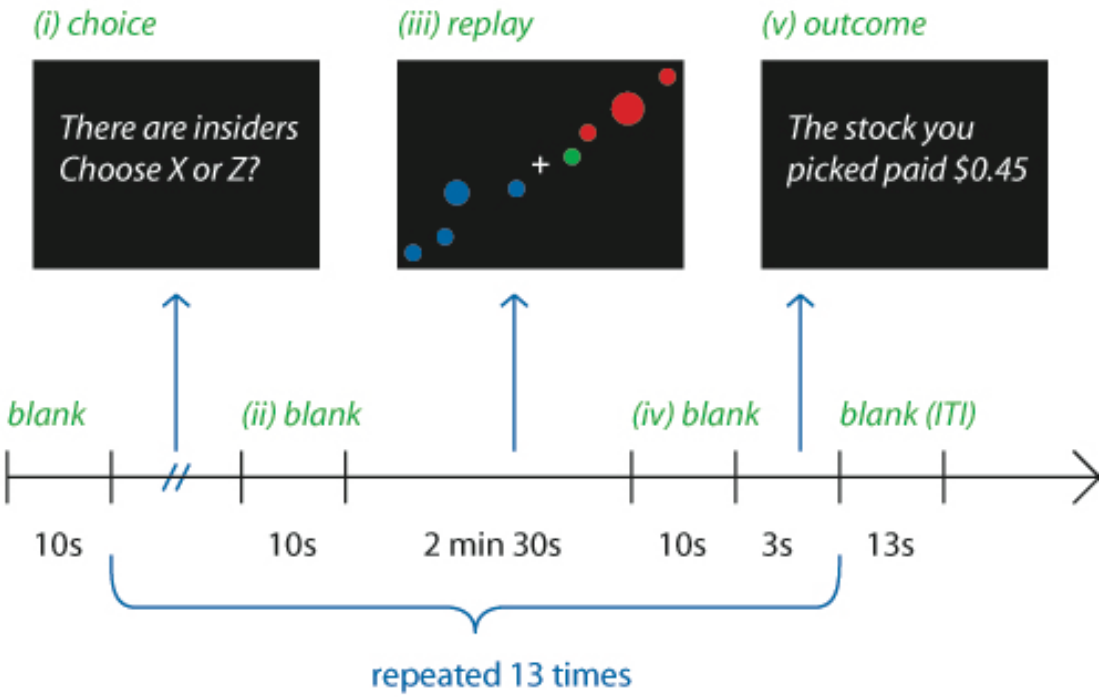


Figure IA1. Timeline of fMRI experiment and sample screenshots. (i) At the start of each session, subjects were shown a screen that informed them of whether or not the session contained insiders and instructed them to make a choice (a blind bet) between stock X or the (complementary) stock Z. They were then endowed with 10 units of the stock they chose. (ii) A blank screen was subsequently presented for 10 seconds, (iii) a market session was then replayed at double speed (the screenshot shown is illustrative; red circles indicated asks; blue circles indicated bids; orders turned green for 0.5 seconds to indicate a trade; bids and asks were arranged along the diagonal or counter-diagonal in increasing order of price; price level was displayed inside the circle (not shown); size of circles correlated with number of units available at the corresponding price), (iv) after the session, a blank screen was shown again for 10 seconds, after which (v) subjects were informed of the dividend paid to the stock they had chosen. This was repeated 13 times (for the 13 sessions in the markets experiment). ITI="inter session interval."

We replayed the order and trade flow (section (iii) of Figure IA1) with an intuitive interface (Video IA1). This video-game-like representation was necessary for

fMRI analysis. Indeed, the more complex the representation is, the higher the number of unwanted signal processes in the brain. The representation contains all the information actual traders in the markets experiment had, but does not have trading functionality.

Available at: http://www.bruguier.com/pub/stockvideo.html

Video IA1. Display of the trading activity. Each circle represents an offer to buy (bid, blue circle) or to sell (ask, red circle) at a certain price indicated by the number inside the circle. The diameter of the circle indicates the number of units of the stock offered. This number is the aggregate of all the offers at this price. We ordered the circles by increasing value, along one diagonal, chosen at random. The circles move, grow, and shrink with the incoming orders. Every time a trade occurs, the corresponding circle (bid or ask quote that is involved in the transaction) turns green for 500ms, shrinks by the number of stocks traded, and then returns to its original color (unless no more stocks remain to be traded, in which case it disappears).

Specifically, we represented the price levels for the offers to buy and sell ("bids" and "asks") with a circle. The number inside a circle indicated the price in cents and the

diameter of the circle represented the number of units offered. Blue circles represented bids, and red circles represented asks. For example, if at a given time there was a single bid at 25¢, three asks at 27¢, and one ask at 28¢, the subject would see three circles: a small blue circle with the number 25 inside, a larger red circle with the number 27 inside, and a small red circle with the number 28 inside. A example is in figure IA1 (iii). When a trade occurred at a certain price, the corresponding circle turned green for 500ms, after which the circle's diameter shrank, reflecting the lower number of bids or asks available after trade. In case no more units remained available, the circle would disappear. The circles are aligned roughly along one diagonal of the screen, by increasing price. The middle of the book remained at the center of the screen. As the trading advanced in time, the circles grew, shrank, appeared, and disappeared, reflecting the changes in outstanding asks and bids. We rearranged the circles dynamically to reflect the changes in price levels of the offers and trades. See Video IA1 for examples.

The locomotion between sessions with and without insiders did not display any obvious differences. In order to monitor attention, we asked subjects to press a key every time a trade occurred. Subjects paid a small penalty for missed trades ($0.05).

Discussion of the Design

Our design was chosen purposely. First, the subjects did not trade during the replay (they did have to take positions before the replay). While the question of how the human brain *executes* financial decisions is interesting, we needed first to understand how humans *perceived* or *judged* a stock market with insiders. By not introducing

decision-making, we avoided a confounding factor. Second, the periods without insiders were controls. Since the data acquisition method, the display screens, and the number of traders were the same, the two types of sessions were identical in every respect except for the presence or absence of insiders. Third, by adding a blind bet, we elicited a feeling of "randomness." Indeed, if we had forced subjects to choose stock X for every session, the payoff would have been the same fixed number for every subject. Moreover, we could not have separated an increase in stock price from a higher expected reward, as these two signals would have been perfectly correlated. Instead, by introducing a blind bet, we orthogonalized changes in subjects' expected rewards and stock prices.

Brain Imaging Analysis

During the experiment, subjects were scanned using functional Magnetic Resonance Imaging (fMRI). This technique allows one to locate temporary changes in distribution of oxygenated blood throughout the brain. Concentration of oxygenated blood increases where neurons are active. It is generally understood that this activity reflects signaling from upstream neurons [Goense and Logothetis (2008)]. The fMRI signal is generally referred to as the BOLD signal, short for Blood Oxygen Level Dependent signal.

To identify areas of significant brain activation in the insider sessions relative to the control sessions, we used a standard approach as implemented in the package BrainVoyager. We fit a time series General Linear Model (GLM) to the (filtered, motion-corrected) BOLD signal for each "voxel" (a cubic volume element of $27mm^3$) with, aside

from auxiliary predictors (regressors that capture activation due to motion and visual effects), the following predictors (see Figure IA2 for sample time series plots of the predictors/regressors and the variables used to construct them):

- The expected reward, computed as follows:
    - When there were insiders, the expected reward was proxied by the transaction price (if the subject chooses to bet on X) or 0.50 minus the transaction price (if subject bet on Z).
    - When there were no insiders, the expected reward was set equal to a constant (0.25).

  This construction reflected the following reasoning. During sessions with insiders, a higher price for stock X indicates that the dividend was likely to be higher, resulting in a higher expected reward in the case of a blind bet on stock X and a lower expected reward on stock Z. When there were no insiders, the price does not carry any information, so we kept the expected reward at 0.25 irrespective of the price.

- Two *parametric regressors*, based on the absolute deviation of the stock's trading price and 25¢. One tracked this deviation in sessions with insiders, and the other one in sessions without insiders. When there are insiders, this regressor should quantify the effect of the insiders on the stock price. The separate parametric regressor for sessions without insiders is used as control, against which brain activation during the sessions with insiders could be compared.

- Two *block regressors* (dummy variables in the language of econometrics), to identify sessions with and without insiders – to capture activation not modulated by the transaction price.

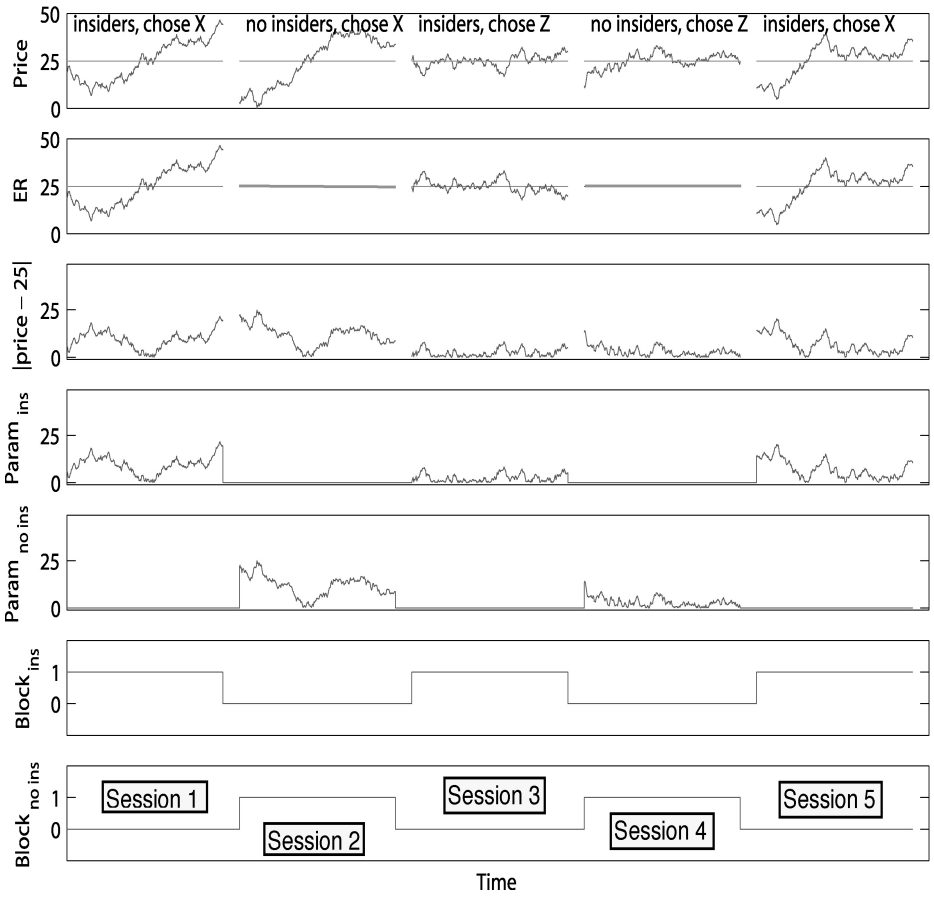


Figure IA2. Construction of predictors in the GLM used in the analysis of brain activation data. Shown are five fictive periods of different combinations of presence/absence of insiders and whether the subject chose stock X or Z. On top, the evolution of the stock price of X is displayed; this price was used to construct parametric predictors. The first parametric predictor was the expected reward (ER); it was computed from the stock price, the presence/absence of insiders, and the blind bet (see main text for detail). As a proxy of insider activity, we used the absolute value of the difference between the trading price (top) and 25¢ (|price-25|). From this proxy, two parametric predictors were constructed. First, a parametric predictor ($Param_{Ins}$) modeled the effect of insider activity during session with insiders. Second, an analogous predictor ($Param_{no\ Ins}$) was constructed for sessions without insiders. In addition, we added the following block predictors (dummy variables): a block predictor capturing mean brain activation during sessions with insiders ($Block_{Ins}$), and a block predictor capturing mean brain activation during sessions without insiders ($Block_{no\ Ins}$).

The effect of neuronal activation on blood oxygen level is both delayed and spread over time. Thus a sharp, on/off neuronal signal related to, e.g., a change in the expected reward, will not result in a sharp, on/off response in the BOLD signal. Instead, we expect to see a smooth ramping up and down. The effect is referred to as the "hemodynamic response," and the function known to describe this response is a gamma function. The impact of a sequence of changes in a regressor is additive. Because of this, all regressors only needed to be ***convolved*** with this hemodynamic response function. Effectively, we transformed the original time series of a predictor x_i to a new time series y, as follows:

$$y(t) = \sum_{k=0,1,2,\ldots} x(t-k)h(k),$$

where h is the hemodynamic response function and t denotes time.

We then fit the transformed regressors to the BOLD signal using least squares:

$$BOLD(t) = b_0 + \sum_i b_i y_i(t) + e(t)$$

We used Generalized Least Squares, because the error process e is (first-order) autocorrelated.

The GLS is repeated for all other subjects, providing a cross-section of estimated slope coefficients b_i, referred to as betas, and more importantly, their differences (difference between a beta for the insider sessions and the corresponding beta for the control sessions). The t statistic and associated p value are then computed using

standard analysis of random effects models (thus assuming that subject-specific betas reflect both a population effect and an individual effect).

We repeat this procedure for every voxel in the brain. For each difference in betas, this gives us a geometric map of *t* statistics. We eliminate of voxels where the *t* statistic does not reach a cut-off *p* value (here: $p<0.001$) or for which neighboring voxels (here: at least 4) do not reach this cut-off *p* level. The result is a map like the one displayed in Figure 1 in the main text of the paper.

Results

We found a significant contrast in the betas for the *parametric regressors* in one large region of paracingulate cortex (PCC; Figure 1 in the main text of the paper and re-produced here as Figure IA3 (a), and Table IAI). The contrast reveals that activation in PCC is more sensitive to deviations of prices from 0.25 during sessions with insiders than during sessions without insiders. We also found significant differences in the betas across insider sessions and sessions without insiders in a smaller region in the frontal part of the anterior cingulate cortex (Figure 1 in the main text of the paper and re-produced here as Figure IA3 (a), and Table IAI). Finally, we found strong differential sensitivity to deviations of prices from 0.25 in right amygdala (Figure IA3 (b) and Table IAI) and left insula (Figure IA3 (c) and Table IAI).

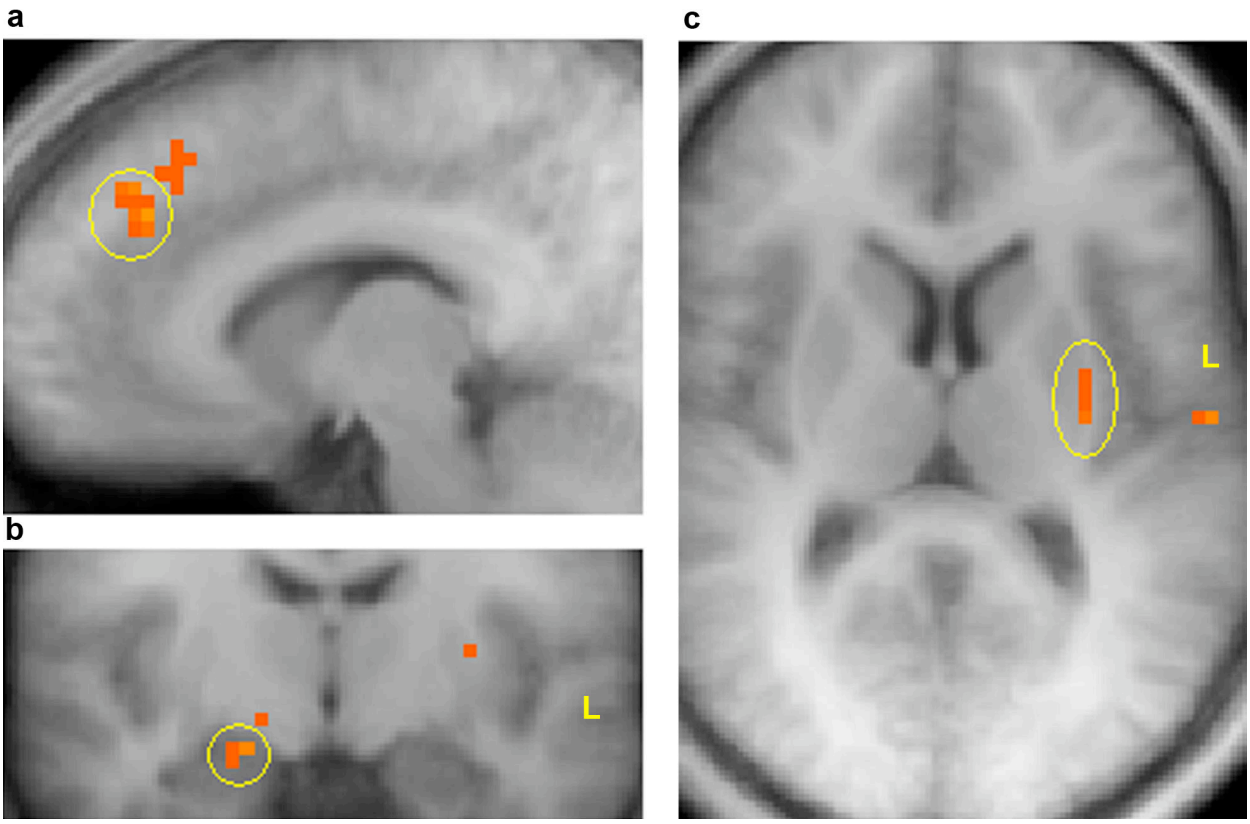


Figure IA3. Location of significant contrasts of slope coefficients ("betas") of the parametric regressors between insider and no-insider sessions (p<0.001, random effects, minimum cluster size=5 voxels): (a) Sagittal view of the activation in paracingulate cortex (Talairach coordinates -9; 41; 36; Brodmann areas 9/32; extends for 22 voxels). (b) Amygdala activation in coronal view (-14; 23; 39; extends for 5 voxels). (c) Activation of the left insula in axial view (-30; -7; 11; extends for 5 voxels).

X	Y	z	cluster size	t_{17}	Area
-30	-7	11	5	4.476	left insula
-14	23	39	5	4.688	frontal part of the anterior cingulate cortex
-9	41	36	22	5.380	paracingulate cortex
-9	32	45	6	4.290	frontal part of anterior cingulate cortex
17	36	43	6	6.322	frontal part of the anterior cingulate cortex
21	-10	-12	5	5.160	right amygdale

Table IAI. Areas with significant difference in slope coefficients ("betas") to parametric regressors (insiders vs. no-insider). Standard coordinates (Talairach x,y,z) are used. We report regions with 5 or more voxels of 27mm^3 each activated at p<0.001 for a random effect GLM. The parametric regressor is the absolute difference between the last traded price and the 25¢. The cluster size is specified in number of contiguous voxels. t_{17} indicates t statistic for the difference in betas (17 degrees of freedom).

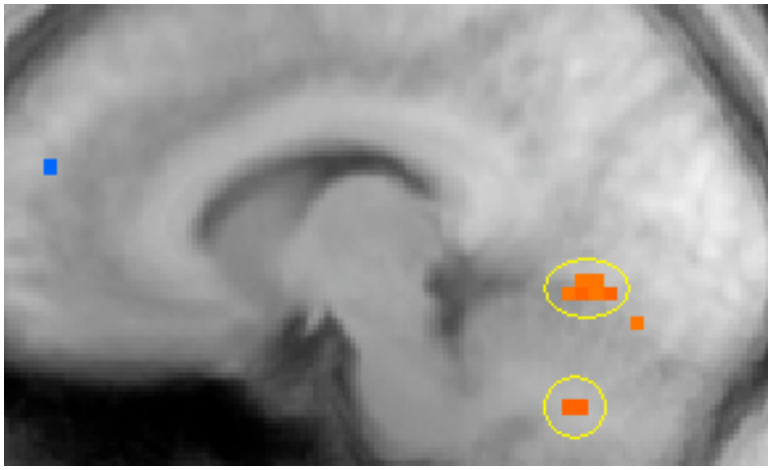


Figure IA4. Location of significant contrast of slope coefficients ("betas") of the block regressors between insider and no-insider sessions. Threshold: $p<0.001$ (minimum cluster size=5 voxels; random effect). There are two clusters of activated voxels, one in the lingual gyrus and the other in cerebellum.

Significant contrasts for the *block predictors* showed up in a large area of lingual gyrus (Figure IA4 and Table IAII), as well as a small area of cerebellum (Figure IA4 and Table IAII). No other areas with five or more voxels exhibited significant contrasts (at $p=0.001$).

x	Y	z	cluster size	t_{17}	Area
-13	-58	-30	9	4.485	Cerebellum
-9	-65	-6	25	4.440	lingual gyrus

Table IAII. Areas with significant difference in slope coefficients ("betas") for block regressors (insiders vs. no-insider). Standard coordinates (Talairach x,y,z) are used. Random effects, thresholded at $p<0.001$ and with minimum cluster size=5. t_{17} indicates t statistic for difference in betas (17 degrees of freedom).

These results suggested that Theory of Mind (ToM) is involved when subjects are facing markets with insiders. Indeed, the activated brain regions belong to the brain circuitry that is known to be engaged in traditional ToM tasks.

- PCC (paracingulate cortex) activation is standard in tasks involving ToM [Gallagher and Frith (2003)], and in strategic games in particular [Gallagher, Jack, Roepstorff and Frith (2002), McCabe, Houser, Ryan, Smith and Trouard (2001), Bhatt and Camerer (2005)]. The PCC has also been observed in tasks that involved attribution of mental states to dynamic visual images, such as

intentionally moving shapes [Castelli, Happe, Frith and Frith (2000)], and hence, not unlike the circles in our display that represent offers.

- We found that activation in the right amygdala and the left anterior insula increased as transaction prices deviated from the uninformed payoff. While a number of studies have reported the involvement of these structures in ToM tasks [Baron-Cohen, Ring, Wheelwright and Bullmore (1999), Critchley, Mathias and Dolan (2001), King-Casas, Sharp, Lomax-Bream, Lohrenz, Fonagy and Montague (2008)], they are more typically regarded as involved in affective features of social interaction. Specifically, the amygdala is a critical structure in the recognition of facial emotional expressions of others [Phillips, Young, Scott, Calder, Andrew, Giampietro, Williams, Bullmore, Brammer and Gray (1999), Phan, Wager, Taylor and Liberzon (2002), Morris, Ohman and Dolan (1998)] while the anterior insula is thought to play a critical role both in subjective emotional experience [Bechara and Damasio (2005)] and in the perception/empathetic response to the emotional state of others [Singer, Seymour, O'Doherty, Kaube, Dolan and Frith (2004)]. A complementary interpretation of insula activation is that it may reflect subjects' own emotional responses to the winner's curse in markets with insiders, which would square our finding with activation of insula when trust is broken during play of the trust game [King-Casas, Sharp, Lomax-Bream, Lohrenz, Fonagy and Montague (2008)]. Another possible interpretation is that subjects perceive more risk when there are insiders. This would be consistent both with a recent report that insula is involved in financial risk learning [Preuschoff, Quartz and Bossaerts

(2008)] and with psycho-physiological evidence that financial market participation engages somatic marker (emotional) circuitry during heightened market volatility [Lo and Repin (2002)]. Future research should shed more light on potential links between market participation, emotions and risk assessment.

- We also found activations in the frontal part of the ACC (anterior cingulate cortex). Our activation is in a slightly more posterior and dorsal location than when ToM is used in strategic and non-anonymous, simple two-person games [Gallagher, Jack, Roepstorff and Frith (2002), McCabe, Houser, Ryan, Smith and Trouard (2001)].
- The increased activation of lingual gyrus in the presence of insiders provides further support for the role of ToM in market perception. For example, the lingual gyrus is involved in perception of biological motion, a key cue for mentalizing [Servos, Osu, Santi and Kawato (2002)]. However, increased activation of lingual gyrus may also be related to accounts that this structure activates in complex visual tasks where subjects are asked to extract global meaning despite local distractors [Fink, Halligan, Marshall, Frith, Frackowiak and Dolan (1996), Fink, Halligan, Marshall, Frith, Frackowiak and Dolan (1997)]. When there are no insiders, subjects can concentrate on the task we imposed, namely, to track trades. In our display, transactions were a local feature, indicated by changes in color of circles in the middle of the screen. In contrast, when there were insiders, the entire list of orders may have reflected information with which to re-evaluate the likely payoff on the securities, but at the same time subjects are still asked to report all transactions, which then

amounted to a local distraction. Future research should determine to what extent lingual gyrus activation reflects ToM (through motion of objects) or the proverbial conflict between the "forest" (insider information) and the "trees" (trades).

We did not observe significant differences in betas (at p=0.001 and with requiring clusters of at least 5 significant adjacent voxels) between sessions with and without insiders in any other brain areas.

Curiously, no differential activation emerged for brain regions known to engage in formal mathematical reasoning. In particular, there was no evidence of estimation of probabilities [Parsons and Osherson (2001)] or arithmetic computation [Dehaene, Spelke, Pinel, Stanescu and Tsivkin (1999)]. We also did not observe any significant activation in brain areas related more generally to logical problem-solving or analytical thought [Newman, Carpenter, Varma and Just (2003)] or reasoning [Acuna, Eliassen, Donoghue and Sanes (2002)]. This finding has also been highlighted in a recent study of ToM in strategic games [Coricelli and Nagel (2009)].

Part 2. Parameters For The Markets Experiment

Type	*Stock X*	*Stock Z*	*Notes*	*Cash*
1	0	7	0	$1.75
2	10	3	0	$0.75

Table IAIII. Subjects in the Markets Experiment were of one of two types, differentiated by initial allocations. Shown are initial holdings of X, Z, Notes and Cash.

Session	Length	Insiders?	How Many Insiders?	Who Knows How Many Insiders?	Signal	Outcome (x)
1	5'	Yes	6	Everyone	0.25	0.21
2	5'	Yes	2	Insiders Only	0.39	0.43
3	5'	Yes	2	Everyone	0.27	0.26
4	5'	No	0	N/A	N/A	0.10
5	5'	Yes	10	Insiders Only	0.38	0.34
6	5'	Yes	2	Nobody	0.39	0.42
7	5'	Yes	16	Everyone	0.09	0.01
8	5'	No	0	N/A	N/A	0.34
9	5'	Yes	6	Insiders Only	0.21	0.19
10	5'	Yes	10	Everyone	0.42	0.42
11	5'	Yes	6	Nobody	0.33	0.25
12	5'	Yes	14	Insiders Only	0.43	0.36
13	5'	Yes	10	Nobody	0.24	0.21

Table IAIV. Insiders, signals and outcomes across the 13 sessions.

Part 3. Instruction Set For The Markets Experiment

(See also http://clef.caltech.edu/exp/info/instructions.html)

Instructions

1. Situation

The experiment consists of a number of replications of the same situation, referred to as ***periods***. At the beginning of each period, you will be given ***securities*** and ***cash***. Markets will open and you will be free to trade some of your securities. You buy securities with cash and you get cash if you sell securities. At the end of the period, the securities expire, after paying ***dividends*** that will be specified below.

Your ***period earnings*** has two components: the dividends on the securities you are holding after markets close, plus your cash balance.

Period earnings are ***cumulative*** across periods. At the end of the experiment, the cumulative earnings are yours to keep, in addition to a standard sign-up reward.

During the experiment, accounting is done in real dollars.

2. The Securities

You will be given two types of securities, ***stocks*** and ***bonds***. Bonds pay a fixed dividend at the end of a period,

namely, $0.50. Stocks pay a random dividend. There are two types of stocks, referred to as X and Z. Their payoffs depend on the drawing of a variable *x*, which is a number between 0 and 0.50. The payoffs on stocks X and Z are complementary: Stock X pays $*x*, and stock Z pays $0.50-*x*, as displayed in the following table.

	Stock X	**Stock Z**	**Bond**
Dividend	$*x*	$0.50-*x*	$0.50

You will be able to trade Stock X as well as the Bond, but *not* Stock Z.

You won't be able to *buy* Stock X or bonds unless you have the cash. You will be able to *sell* Stock X and the Bond (and get cash) even if you do not own any. This is called *short selling*. If you sell, say, one Stock X, then you get to keep the sales price, but $*x* will be subtracted from your period earnings after the market closes. If at the end of a period you are holding, say, -1 Bond, $0.50 will be subtracted from your period earnings.

The trading system checks your orders against *bankruptcy*: you may not be able to submit orders which, if executed, could generate negative period earnings.

3. Inside information

For each period, *x* is drawn randomly from the numbers {0.01, 0.02, 0.03, ..., 0.49, 0.50}. Outcomes in previous periods have no effect on the drawing. The draw is not disclosed to anybody until the end of the period.

Some participants, however, may get ***inside information*** about x before the start of trading. This will take the following form. A *signal* S is drawn from the numbers $\{x\text{-}0.10, x\text{-}0.09, x\text{-}0.08, ..., x\text{+}0.09, x\text{+}0.10\}$. E.g., if x is 0.30, then S is drawn from {0.20, 0.21, 0.22, ..., 0.39, 0.40}. You can use S to infer what x could be: if S is 0.05, then x could be anywhere from 0.01 to 0.15.

This signal S is then revealed to some participants. The *same* signal is revealed to all insiders.

The number and identities of participants who receive inside information vary across periods. Sometimes nobody receives inside information. In certain periods when inside information is distributed, only insiders know the number of insiders while in others nobody is told this number. This is made clear in the ***News page***.

Part 4. Instruction Set For The fMRI Experiment

Instructions

Market Replay Experiment

Setup

In this experiment we replay several episodes, "periods," of a real securities market. You will see the history of the order flow (buys; sells) and the trades precisely as they happened. Your actions will obviously not have any effect on the history. However, you incur the same risk as some players did in the market – without the ability to trade.

There were two types of securities in the market, stocks and bonds. Bonds paid a fixed dividend at the end of a period, namely, $0.50. Stocks paid a random dividend. There were two types of stocks, referred to as X and Z. Their payoffs depended on the drawing of a variable *x*, which is a number between 0 and 0.50. The payoffs on stocks X and Z were complementary: Stock X paid $*x*, while stock Z paid $0.50-*x*.

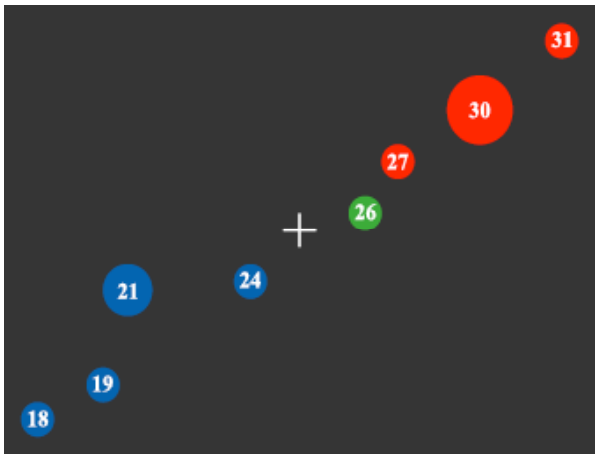
You will be exposed to the risk of either stock X or stock Z. Before the experiment starts, you choose which stock you want to be exposed to. You only see a

replay of the history of the market for stock X, even if you choose to be exposed to the risk of Stock Z.

Details of the markets are provided in the attached sheets. These were the instruction sheets for the market players. They explain you exactly what the players knew. They also provide details on how the payoffs on the securities are determined.

Replay Screen

We replay the history of the offers and the trades. A typical screen is reproduced below. Each bubble represents a current standing order. Blue bubbles are buy orders and red bubbles are sell orders. For example, the blue bubble with the number "24" inside stands for an order to buy at $0.24. The size of the bubble corresponds to the number of units offered. Because the size of the blue bubble with price $0.21 is twice that of the bubble with price $0.24, there are twice as many standing offers (to buy) at $0.21 than at $0.24.



Only offers for the five best price levels are shown. There might be more offers at inferior prices. Orders with higher price levels are always above those with lower price levels. The bubbles shrink or may even disappear when market players cancel orders. They also shrink or disappear after an order is taken, in which case there is a trade. If that happens, the bubble will first turn green for one second before shrinking or disappearing.

Your Task

Besides watching the orders and trades, you are to perform a simple task. Each time you see a trade, you immediately press a button. You will be penalized if you fail to do so or if you do so incorrectly. Button presses obviously have no impact on the history of the market; nor do they influence the risk of the security you are exposed to.

How You Make (Or Lose) Money

The amount of money you receive depends on the payoff on the security that you choose to be exposed to. Orders and transaction prices in the replay of the market do not determine your earnings, although they may be a good indicator of the likely payoff.

Indeed, sometimes inside information about the payoff was available. The number and identities of players who received inside information varied across periods. Sometimes nobody received inside information; in other periods, inside information was available, but only insiders knew how many players had received the information; while in the remaining periods, everyone was told how many insiders there were. This will be made clear in the first screen you see before a market is replayed.

The attached instructions sheets for the market players provide details of the nature of the inside information.

Attachment: Instructions For Market Players

(http://clef.caltech.edu/exp/info/instructions.html)

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Dividend	$*x*	$0.50-*x*	$0.50

You will be able to trade Stock X as well as the Bond, but *not* Stock Z.

You won't be able to *buy* Stock X or bonds unless you have the cash. You will be able to *sell* Stock X and the Bond (and get cash) even if you do not own any. This is called *short selling*. If you sell, say, one Stock X, then you get to keep the sales price, but $*x* will be subtracted from your period earnings after the market closes. If at the end of a period you are holding, say, -1 Bond, $0.50 will be subtracted from your period earnings.

The trading system checks your orders against *bankruptcy*: you may not be able to submit orders which, if executed, could generate negative period earnings.

3. Inside information

For each period, *x* is drawn randomly from the numbers {0.01, 0.02, 0.03, ..., 0.49, 0.50}. Outcomes in previous periods have no effect on the drawing. The draw is not disclosed to anybody until the end of the period.

Some participants, however, may get ***inside information*** about x before the start of trading. This will take the following form. A *signal* S is drawn from the numbers $\{x\text{-}0.10, x\text{-}0.09, x\text{-}0.08, ..., x\text{+}0.09, x\text{+}0.10\}$. E.g., if x is 0.30, then S is drawn from $\{0.20, 0.21, 0.22, ..., 0.39, 0.40\}$. You can use S to infer what x could be: if S is 0.05, then x could be anywhere from 0.01 to 0.15.

This signal S is then revealed to some participants. The *same* signal is revealed to all insiders.

The number and identities of participants who receive inside information vary across periods. Sometimes nobody receives inside information. In certain periods when inside information is distributed, only insiders know the number of insiders while in others nobody is told this number. This is made clear in the ***News page***.

Part 5. Instruction Set For Behavioral Experiment

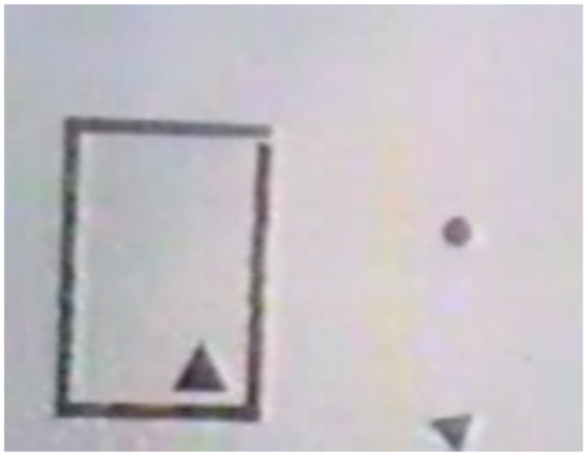
In this experiment, you are given four (4) problem-solving tasks. Your earnings depend on how well you do on each of them. The tasks cover a broad range of skills, so if you feel that one task is hard, another one may be easy for you.

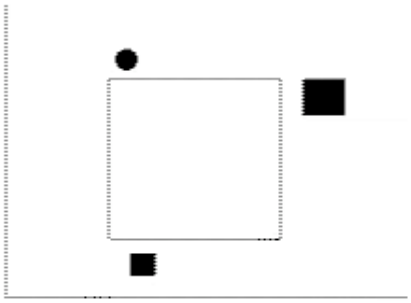
The four tasks are:

1. *Moving Objects Task*: you are asked to predict movements of geometric shapes
2. *Stock Market Task*: you are asked to predict stock price movements
3. *Faces Task*: you are asked to describe the intentions, beliefs or emotions reflected in a person's gaze
4. *Riddles Task*: you are asked to solve a number of logic problems

You will be invited to perform these tasks in random order.

Moving Objects Task





First movie: predict moves of large triangle

Second movie: predict moves of the large square

You will watch <u>two</u> movies of three geometric objects: a circle, and two squares or two triangles, one small and the other one large. The objects move around, into, inside and out of a box.

In the *first movie*, with a circle and two triangles, you are asked to predict the movement of the large triangle. The movie will be stopped after 10s, at which point you will be given 5s to choose whether, in 10s, the large triangle is going to be *closer to* or

farther away from the small triangle than at present. You indicate your choice with the arrow keys: push the "up" key if you think the large triangle is going to be farther away; push the "down" key if you think it will be closer; push the "right" key if you think the large triangle will remain at the same distance.

In the *second movie*, with a circle and two squares, you are asked to predict the movement of the large square. The movie will be stopped every 10s, at which point you will be given 5s to choose whether, in 10s, the large square is going to be closer to or farther away from the small square. You indicate your choice with the arrow keys, just like for the first movie.

After your choice, we play the movie for another 10s, stop the movie again, and a message will be displayed to indicate whether you won (if your prediction was right), or whether you pay a penalty because you failed to make a decision within the allotted time.

We then re-start the movie for 10s, after which you are again asked to predict the movement of the large triangle (first movie) or large square (second movie), etc. We will continue these cycles until the end of the movie.

You win $1 for every correct prediction. You pay a penalty of $0.25 for any failure to decide.

Stock Market Task

In this test, you are asked to predict price changes in a market where students traded a stock for real money.

Explanation Of The Stock Market

About one year ago, we collected trading data in a financial markets experiment that was set up as follows. In a large computer room, 20 students were given cash, as well as a certain number of a security called *stock*. They could trade this stock over an anonymous electronic market. When market closed, the stock expired, after paying a *dividend*. This dividend was anywhere between ¢0 and ¢50. The traders were not told the exact size of the dividend before markets closed.

Traders' earnings depended on the cash they were holding at the end of trading, as well as the number of stock and the stock's dividend. For example, if, after markets close, trader Alice owned $2 in cash and 10 units of the stock, and if the dividend was ¢45, Alice was paid $2 + 10 x $0.45 = $6.50. Note that the prices at which Alice could have traded the stock do not directly influence Alice's earnings; it would, of course, have

affected her cash holdings (if she bought one unit of the stock at ¢35, then ¢35 would have been subtracted from her cash holdings).

We repeated this situation several times. Every repetition is referred to as a *period*. Periods were independent in that the dividend in one period had no influence on the dividend in another period.

Please note that we actually paid them: the experiment was not a "pretend." Students left the trading room with actual money in their hands.

In principle, the stock is worth about ¢25, since it paid a dividend chosen at random between ¢0 and ¢50.

But we did something to make the market more interesting. We separated the traders in two groups: insiders and outsiders. The insiders were given an estimate of the dividend. This estimate was within ¢10 of the true dividend. The outsiders did not get this estimate.

The insiders bias the market. For example, if trader Bob is an insider and has an estimate of the dividend of ¢40, he knows that the true dividend of the stock is between ¢30 and ¢50. If he sees an offer to sell the stock at ¢25, he would want to accept the offer. He would make a profit of *at least* ¢5 and *up to* ¢25 per unit bought. But because Bob buys the stock, its price tends to increase, which is what we mean when we state that insiders bias the market.

Both insiders and outsiders must act with care. Insiders must trade discreetly in order to avoid revealing their knowledge of the estimate to outsiders. Similarly, outsiders need to observe the trades carefully in order not to buy at too high a price or sell at too low a price.

Your Task

We will replay four periods exactly as they happened. Every so often, you will be asked to predict the price at which the stock will trade 10s later.

Replay Interface

We will use an intuitive graphical display of the orders and trades in the electronic market.

To understand this display, you should know how trade took place. At any time, traders could submit *offers to sell or to buy a certain number of stock at a certain price*. For example, trader Alice may offer to sell 3 units at ¢37 and trader Bob may offer to buy 2 units at ¢35. If Alice decides that a sales price of ¢35 isn't bad after all, she may cancel two units of her sell offer at ¢37 and sell these two units at ¢35 by submitting a sell offer for two units at a price of ¢35 or lower. Thus, actual sales take place when a trader submits a sell offer at a price at least as low as the highest buy offer; actual purchases take place when a trader submits a buy order at a price at least as high as the lowest sell offer.

Remember that our market was anonymous. It means that even though everyone could see all the offers, *nobody knew where they came from*. Participants did not know how many traders there were in the marketplace, let alone what other traders' holdings of cash and stock were.

In the graphical replay of the market, bubbles correspond to offers in the marketplace. See the sample video. *Blue bubbles* are offers to buy stock and the *red bubbles* are offers to sell stock. The number inside the bubbles indicates the price (in

cents). The size of the bubble indicates the number of units offered at the indicated price. All the offers are aligned along one diagonal, decreasing in price. Bubbles move constantly so that the best buy offer and the best sell offer at any moment in time stay close to the middle of the screen.

Trades are shown in green. They flash for half a second, after which the bubble shrinks or disappears, to indicate the reduction in the number of units offered as a consequence of the trade.

From one period to another, we will randomly change the diagonal along which offers and trades are displayed.

Your Task In Detail

So what do you have to do? We want you to predict the stock price changes.

Every 10s, we stop the replay. At every stop, you will be reminded of the latest trading price and we will ask you to make a prediction: will the transaction price in 10s

be higher, lower, or the same as the latest transaction price? Use the keyboard to enter your prediction:

- up arrow: trade price will go up
- down arrow: trade price will go down
- right arrow: trade price will stay the same

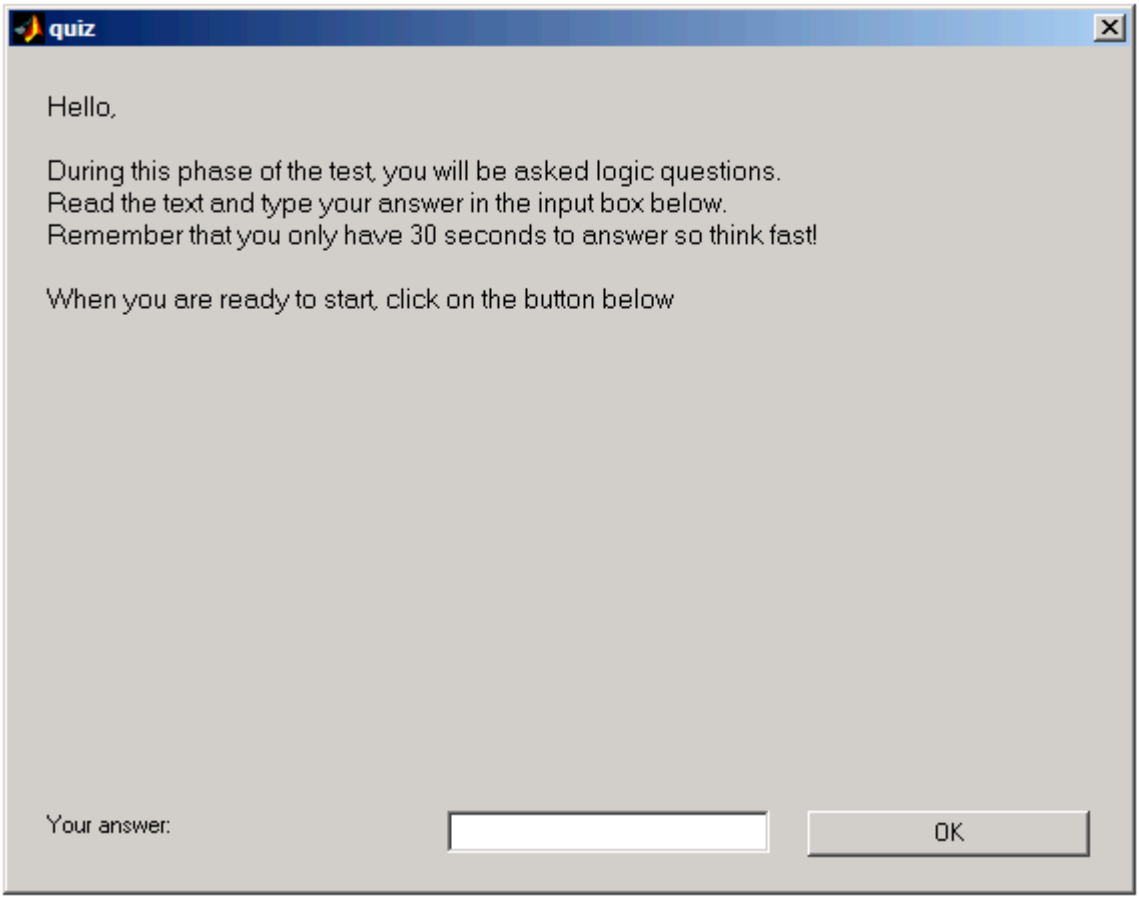
Remember, we are asking about the trade prices (trades are indicated by *green flashing of offer bubbles*), not the buy or sell offer prices. If no trade takes place in the subsequent 10s, we assume that the trade price stays the same.

You will be given 5s to respond. After that, we re-start the replay for 10s. At the end of this 10s interval, we briefly stop the replay once more, to indicate whether you won, or whether you paid a penalty because you did not choose within the allotted 5s.

We then restart the replay for another 10s, after which we stop and ask again for a prediction. These cycles continue until markets close.

You will make $1 for every correct prediction. If you fail to answer within the allotted 5s, you will be fined $0.25.

Riddles Task



In this task, we want you to solve logic problems. The interface should look as above.

You will have 30s to read the question, to type your answer in the field at the bottom and to click OK.

There are 7 problems, and you will be paid $2 for each correct answer. You pay $1 when you fail to provide an answer within the allotted 30s.

Faces Task

In this task, we want you to interpret a person's gaze. The interface should look as above.

For each gaze, click on the term that best describes what the person in the picture is thinking or feeling. You may feel that more than one term is applicable but

please choose just one term. Before making your choice, make sure that you have read all four (4) terms!

You will only have 10 seconds to observe the person's gaze, to read the terms and to indicate your chocie. There will be 36 trials, and you will be paid $0.25 for each correct answer. You pay $0.10 each time you fail to make a choice within the allotted time.

Before we start the test, please take some time to read the definitions of the terms we'll be using. These are listed on the next page.

ACCUSING blaming

The police officer was accusing the man of stealing a wallet.

AFFECTIONATE showing fondness towards someone

Most mothers are affectionate to their babies by giving them lots of kisses and cuddles.

AGHAST horrified, astonished, alarmed

Jane was aghast when she discovered her house had been burglarized.

ALARMED fearful, worried, filled with anxiety

Claire was alarmed when she thought she was being followed home.

AMUSED finding something funny

I was amused by a funny joke someone told me.

ANNOYED irritated, displeased

Jack was annoyed when he found out he had missed the last bus home.

ANTICIPATING expecting

At the start of the soccer match, the fans were anticipating a quick goal.

ANXIOUS worried, tense, uneasy

The student was feeling anxious before taking her final exams.

APOLOGETIC feeling sorry

The waiter was very apologetic when he spilt soup all over the customer.

ARROGANT conceited, self-important, having a big opinion of oneself

The arrogant man thought he knew more about politics than everyone else in the room.

ASHAMED overcome with shame or guilt

The boy felt ashamed when his mother discovered him stealing money from her purse.

ASSERTIVE confident, dominant, sure of oneself

The assertive woman demanded that the shop give her a refund.

BAFFLED confused, puzzled, dumbfounded

The detectives were completely baffled by the murder case.

BEWILDERED utterly confused, puzzled, dazed

The child was bewildered when visiting the big city for the first time.

CAUTIOUS careful, wary

Sarah was always a bit cautious when talking to someone she did not know.

COMFORTING consoling, compassionate

The nurse was comforting the wounded soldier.

CONCERNED worried, troubled

The doctor was concerned when his patient took a turn for the worse.

CONFIDENT self-assured, believing in oneself

The tennis player was feeling very confident about winning his match.

CONFUSED puzzled, perplexed

Lizzie was so confused by the directions given to her, she got lost.

CONTEMPLATIVE reflective, thoughtful, considering

John was in a contemplative mood on the eve of his 60th birthday.

CONTENTED satisfied

After a nice walk and a good meal, David felt very contented.

CONVINCED certain, absolutely positive

Richard was convinced he had come to the right decision.

CURIOUS inquisitive, inquiring, prying

Louise was curious about the strange shaped parcel.

DECIDING making your mind up

The man was deciding whom to vote for in the election.

DECISIVE already made your mind up

Jane looked very decisive as she walked into the polling station.

DEFIANT insolent, bold, don't care what anyone else thinks

The animal protester remained defiant even after being sent to prison.

DEPRESSED miserable

George was depressed when he didn't receive any birthday cards.

DESIRE passion, lust, longing for

Kate had a strong desire for chocolate.

DESPONDENT gloomy, despairing, without hope

Gary was despondent when he did not get the job he wanted.

DISAPPOINTED displeased, disgruntled

The Red Sox fans were disappointed not to win the World Series.

DISPIRITED glum, miserable, low

Adam was dispirited when he failed his exams.

DISTRUSTFUL suspicious, doubtful, wary

The old woman was distrustful of the stranger at her door.

DOMINANT commanding, bossy

The sergeant major looked dominant as he inspected the new recruits.

DOUBTFUL dubious, suspicious, not really believing

Mary was doubtful that her son was telling the truth.

DUBIOUS doubtful, suspicious

Peter was dubious when offered a surprisingly cheap television in a pub.

EAGER keen

On Christmas morning, the children were eager to open their presents.

EARNEST having a serious intention

Harry was very earnest about his religious beliefs.

EMBARRASSED ashamed

After forgetting a colleague's name, Jenny felt very embarrassed.

ENCOURAGING hopeful, heartening, supporting

All the parents were encouraging their children in the school sports day.

ENTERTAINED absorbed and amused or pleased by something

I was very entertained by the magician.

ENTHUSIASTIC very eager, keen

Susan felt very enthusiastic about her new fitness plan.

FANTASIZING daydreaming

Emma was fantasizing about being a film star.

FASCINATED captivated, really interested

At the seaside, the children were fascinated by the creatures in the rock pools.

FEARFUL terrified, worried

In the dark streets, the women felt fearful.

FLIRTATIOUS brazen, saucy, teasing, playful

Connie was accused of being flirtatious when she winked at a stranger at a party.

FLUSTERED confused, nervous and upset

Sarah felt a bit flustered when she realised how late she was for the meeting and that she had forgotten an important document.

FRIENDLY sociable, amiable

The friendly girl showed the tourists the way to downtown.

GRATEFUL thankful

Kelly was very grateful for the kindness shown by the stranger.

GUILTY feeling sorry for doing something wrong

Charlie felt guilty about having an affair.

HATEFUL showing intense dislike

The two sisters were hateful to each other and always fighting.

HOPEFUL optimistic

Larry was hopeful that the post would bring good news.

HORRIFIED terrified, appalled

The man was horrified to discover that his new wife was already married.

HOSTILE unfriendly

The two neighbors were hostile towards each other because of an argument about loud music.

IMPATIENT restless, wanting something to happen soon

Jane grew increasingly impatient as she waited for her friend who was already 20 minutes late.

IMPLORING begging, pleading

Nicola looked imploring as she tried to persuade her dad to lend her the car.

INCREDULOUS not believing

Simon was incredulous when he heard that he had won the lottery.

INDECISIVE unsure, hesitant, unable to make your mind up

Tammy was so indecisive that she couldn't even decide what to have for lunch.

INDIFFERENT disinterested, unresponsive, don't care

Terry was completely indifferent as to whether they went to the cinema or the pub.

INSISTING demanding, persisting, maintaining

After a work outing, Frank was insisting he paid the bill for everyone.

INSULTING rude, offensive

The baseball crowd was insulting the umpire after he gave a invalidated the home-run.

INTERESTED inquiring, curious

After seeing Jurassic Park, Hugh grew very interested in dinosaurs.

INTRIGUED very curious, very interested

A mystery phone call intrigued Zoe.

IRRITATED exasperated, annoyed

Frances was irritated by all the junk mail she received.

JEALOUS envious

Tony was jealous of all the taller, better-looking boys in his class.

JOKING being funny, playful

Gary was always joking with his friends.

NERVOUS apprehensive, tense, worried

Just before her job interview, Alice felt very nervous.

OFFENDED insulted, wounded, having hurt feelings

When someone made a joke about her weight, Martha felt very offended.

PANICKED distraught, feeling of terror or anxiety

On waking to find the house on fire, the whole family was panicked.

PENSIVE thinking about something slightly worrying

Susie looked pensive on the way to meeting her boyfriend's parents for the first time.

PERPLEXED bewildered, puzzled, confused

Frank was perplexed by the disappearance of his garden gnomes.

PLAYFUL full of high spirits and fun

Neil was feeling playful at his birthday party.

PREOCCUPIED absorbed, engrossed in one's own thoughts

Worrying about her mother's illness made Debbie preoccupied at work

PUZZLED perplexed, bewildered, confused

After doing the crossword for an hour, June was still puzzled by one clue.

REASSURING supporting, encouraging, giving someone confidence

Andy tried to look reassuring as he told his wife that her new dress did suit her.

REFLECTIVE contemplative, thoughtful

George was in a reflective mood as he thought about what he'd done with his life.

REGRETFUL sorry

Lee was always regretful that he had never travelled when he was younger.

RELAXED taking it easy, calm, carefree

On holiday, Pam felt happy and relaxed.

RELIEVED freed from worry or anxiety

At the restaurant, Ray was relieved to find that he had not forgotten his wallet.

RESENTFUL bitter, hostile

The businessman felt very resentful towards his younger colleague who had been promoted above him.

SARCASTIC cynical, mocking, scornful

The comedian made a sarcastic comment when someone came into the theatre late.

SATISFIED content, fulfilled

Steve felt very satisfied after he had got his new flat just how he wanted it.

SCEPTICAL doubtful, suspicious, mistrusting

Patrick looked sceptical as someone read out his horoscope to him.

SERIOUS solemn, grave

The bank manager looked serious as he refused Nigel an overdraft.

STERN severe, strict, firm

The teacher looked very stern as he told the class off.

SUSPICIOUS disbelieving, suspecting, doubting

After Sam had lost his wallet for the second time at work, he grew suspicious of one of his colleagues.

SYMPATHETIC kind, compassionate

The nurse looked sympathetic as she told the patient the bad news.

TENTATIVE hesitant, uncertain, cautious

Andrew felt a bit tentative as he went into the room full of strangers.

TERRIFIED alarmed, fearful

The boy was terrified when he thought he saw a ghost.

THOUGHTFUL thinking about something

Phil looked thoughtful as he sat waiting for the girlfriend he was about to break-up with.

THREATENING menacing, intimidating

The large, drunken man was acting in a very threatening way.

UNEASY unsettled, apprehensive, troubled

Karen felt slightly uneasy about accepting a lift from the man she had only met that day.

UPSET agitated, worried, uneasy

The man was very upset when his mother died.

WORRIED anxious, fretful, troubled

When her cat went missing, the girl was very worried

Part 6. Mathematics Section Of Behavioral Experiment:

Questions and Answers

Question	Answer
Consider a game played with a deck of three cards: spades, clubs, and hearts. Your goal is to identify the hearts. The cards are shuffled and displayed in a row, face down. You make your choice. The dealer then turns over one of the two remaining cards, provided it is not hearts. He then offers you the possibility to change your choice and switch to the other card that is left face down. What is the best strategy? Should you switch, stay, or does it not matter? Answer below "switch", "stay" or "either".	switch
Consider a deck of four cards: spades, clubs, hearts, and diamonds. The cards are shuffled and displayed in a row, face down. You choose one card at random and it is discarded. Then the dealer turns over two cards, chosen at random, but provided they are not hearts. Now there is only one card left unturned. If the two cards the dealer turns over are diamonds and clubs, is the probability that the remaining one is hearts more than, less than, or equal to 0.5? Answer below "more", "less" or "same".	More
There are 8 marbles that weigh the same, and 1 marble that is heavier. The marbles are all uniform in size, appearance, and shape. You have a balance with 2 trays. You are asked to identify the heavier marble in at most 2 (two) weightings. How many marbles do you initially have to place on each tray? Input a number below.	3
Divide 100 by 1/2. Is the result more, less than or equal to 100? Answer below "more", "less", or "same".	More
Jenn has half the Beanie Babies that Mollie has. Allison has 3 times as many as Jenn. Together they have 72. Does Mollie have more than, less than, or equal to, 20 Beanie Babies? Answer below "more", "less" or "same".	More
Johnny's mother had three children. The first child was named April. The second child was named May. What was the third child's name? Type the name below.	Johnny

The police rounded up Jim, Bud and Sam yesterday, because one of them was suspected of having robbed the local bank. The three suspects made the following statements under intensive questioning. Jim: I'm innocent. Bud: I'm innocent. Sam: Bud is the guilty one. If only one of these statements turns out to be true, who robbed the bank? Type the name of the robber below.	Jim

Table III. The Mathematical (M) test. We presented subjects with seven questions in a random order. Subjects had 30 seconds to type the answer. We ignored typing mistakes.

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