E-Companion

The Bull of Wall Street: Experimental Analysis of Testosterone and Asset Trading

This E-companion contains supplementary materials. Section 1 details the unabridged methods and experimental design for the experimental sessions. Section 2 provides the complete set of trading instructions and the inter-round survey questions given to the traders involved in the experimental sessions. Section 3 provides variable definitions, robustness checks, and supplementary analyses.

Table of Contents

Section 1. Unabridged Methods and Experimental Design

1.1. Participants. For this double-blind experiment, we recruited 143 male participants from Southern California colleges. Only males were included because the United States Food and Drug Administration has approved the synthetic testosterone drug used in the experiment (Androgel®) only for use in men. The average age of participants was 23 years (SD = 7.0), and the ethnic distribution was 67% White, 13% Asian, 7% Hispanic, 6% Black, 3% Indian, and 4% Other. All participants were paid for their participation in the experiment, and all provided their written informed consent prior to inclusion. The Institutional Review Board of the involved institutions approved this experiment. No adverse reactions were reported.

Each session required two days to complete due to the pharmacokinetics of Androgel®, which peaks in blood in approximately 2 hours, and stabilizes approximately 16 hours after application (Swerdloff et al. 2000).

1.2. Asset Trading. We used a continuous double-auction market with an asset yielding a stochastic dividend, following Smith et al. (1988). The double-auction format allowed participants to simultaneously place bids to buy assets and to place offers to sell assets, thereby mimicking typical trading environments.

For this study, 17 unique groups of traders participated in one session each, with each *session* consisting of three distinct *rounds* of 12 *periods*. The asset paid a dividend of 18 or 0 cents at the conclusion of each period with equal probability, giving it an expected value of 9 cents per period. The fundamental value of the asset began at 108 cents (i.e., 12 × 9) at the start of each round, and decreased by 9 cents each period, reaching a value of zero at the end of each round (i.e., at the end of periods 12, 24, and 36) (see Figure 1). Participants were provided with a chart of the expected value of a share of stock over the duration of 12 periods (see table at the end of the instructions).

Dividends were paid by a stochastic process that was generated internally by z-Tree and was not predetermined by the experimenters. We tested whether dividend realizations followed a random process using the runs test (Bradley, 1968). We define a "run" as a series of increasing or decreasing values, and the number of values is the length of the run. In a random data set, the probability that the $(I + 1)$th value is larger or smaller than the Ith value follows a binomial distribution (for more details of this test see (Bradley 1968)). At the session level, we find that the dividend patterns in 14 out of the 17 sessions were indeed random, using a cut-off alpha of 0.05 and an associated z-score greater than 1.96. The non-random sessions only barely exceeded the threshold (z-scores were 2.05, 2.03, 1.97). At the round level, we find 1 incidence that did not satisfy the randomness criterion in round 1, 9 incidences in round 2, and 1 incidence in round 3 across all sessions; these findings include incidences of both excessive and inadequate alternations between 0 and 18 dividend payouts. Due to this finding, we control for dividend streaks in regression analyses to account for changes in trading stemming from trading in a non-random dividend environment.

Trading was done on z-Tree (Fischbacher 2007). At the start of every round, participants were endowed, by random assignment, with either 6 stocks and 216 cents or 2 stocks and 648 cents (both endowments were monetarily equivalent to 864 cents).

1.3 Procedure. *Day 1*—Upon participants' arrival at the Center for Neuroeconomics Studies at 6 P.M., they were briefed on all aspects of the experiment and were asked to sign a consent form. They were then each assigned an alphanumeric identifying code to maintain their anonymity throughout the experiment. Next, in accordance with clinical instructions, they received a private medical screening by a licensed physician to rule out contraindications for the use of topical androgen gel.

A licensed phlebotomist then obtained a 20 ml blood sample from an antecubital vein using a Vacutainer®, maintaining a sterile field. Next, in a private room, each participant removed his shirt and received a clear gel to apply to his shoulders and upper arms. Testosterone was administered using 10 g of Androgel® 1%, a clear alcohol-based gel containing 1% synthetic testosterone (T). An alcohol-based hand sanitizer of similar consistency was used as the placebo, as was done in Zak et al. (2009). Finally, participants completed a background survey and were instructed to return the following day to complete the experiment.

Day 2—Participants signed in upon their arrival at noon. Next, they were seated and provided with printed instructions, briefed on the structure of the experiment, and instructed to complete a survey. A second 20 ml blood sample was then obtained. Participants were provided an opportunity to ask questions about the trading task prior to starting the trading session.

Between rounds of trading, participants were asked a series of questions to assess their evaluations of their performance, the market prices, the behavior of other participants, and their emotional states. For example, participants were asked "What do you think determined your performance?" and were provided a list of eight criteria: luck, talent, character, calculations, self strategies, self mistakes, other mistakes, and other strategies. Participants were also asked, "What do you think just happened in the last trading session?" and provided with four statements (i.e., prices were higher than expected, lower than expected, fluctuated more than expected, and prices were "about right") to be assessed on a numeric scale (1 = strongly agree; 7 = strongly disagree; see below for the complete survey). At the end of each trading session, participants were privately paid the accumulated amounts of final cash holdings from each round.

Survey—A demographic survey was conducted on day 1 to document each participant's age, ethnicity, field(s) of study, experience trading financial assets, relationship status, and personality traits.

Blood-Handling Procedure—Each blood draw consisted of two 8-ml ethylenediaminetetraacetic acid (EDTA, an anticoagulant) whole blood tubes and one serum-separator tube. Blood tubes were immediately placed on ice following the blood draw. The tubes were then placed in a centrifuge and spun at 1500 rpm for 12 minutes at 4 degrees Celsius. Plasma and serum were pipetted from tubes and placed into 2-ml microtubes with screw caps. These tubes were immediately placed on dry ice and transferred to an 80-degree-Celsius freezer until assayed.

Unit of Analysis—The primary analyses compared sessions in which all participants received testosterone to sessions in which all participants received the placebo. This process enabled us to assess market behavior for elevated testosterone levels versus basal testosterone levels. We also analyzed individual behavior of those receiving testosterone compared with those given the placebo.

Section 2. Trading Instructions

2.1. General Instructions

This is an experiment in financial decision-making where you will earn money based on trades you make. The experiment will have 3 rounds; each Round includes 12 trading periods in which you can buy or sell stocks. All trades will be made in *cents*. Please do not speak with any other participant during this experiment. This part of the experiment will last for approximately one hour, including ten minutes for you to review these instructions.

When the experiment starts, half of the participants will be given 6 shares of stock and 216 cents and the other half will be given 2 shares of stock and 648 cents. Both of these two portfolios are worth 864 cents. You will be randomly assigned one of these portfolios. Six (6) to sixteen (16) traders will participate in the market.

Each trading session has 12 periods that each last for 90 seconds. In each period you may buy or sell units of stock. You can be a buyer and seller of stocks at the same time. Each unit of stock is identical, except the price to purchase or sell. Stocks have a lifespan of 12 periods, and your inventory of stock carries over from one trading period to the next within each trading session.

At the end of each of the 12 trading periods, a dividend is paid for each unit of stock you own at that time. The dividend has a 50% chance of being either 0 or 18 cents. The trading software determines this randomly. As a result, the average dividend per period is 9 cents.

After each trading session, the dividends you earn will be added to your money holdings.

The way to calculate your earnings is described below in Section 3.

You will be asked a series of questions at the beginning of the first trading period and at the end of each trading period. Please answer all these questions.

2.2. Calculating Your Earnings

Your earnings in each period are the dividends you receive based on the number of stocks you hold at the end of the trading period. That is:

YOUR EARNINGS FOR A PERIOD =

DIVIDEND PER UNIT x NUMBER OF UNITS HELD AT THE END OF THE PERIOD

Example: If you own 10 shares and the payout is 18 cents: 18 x 10 = 180

Your total earnings for each session are the total of your dividend earnings for each of the 12 periods plus the amount of cash that you have at the end of period 12.

That is:

EARNINGS FOR PERIOD 1

EARNINGS FOR PERIOD 2

EARNINGS FOR PERIOD 3

EARNINGS FOR PERIOD 4

….

EARNINGS FOR PERIOD 12

CASH ON HAND AT THE END OF PERIOD 12

TOTAL EARNINGS

Your profit is the sum of the profits from the three trading sessions. The computer software will track your progress throughout the experiment and give you the final amount you earned, so no need to calculate this yourself.

2.3. Finding Your Way around the Trading Screen

Period

This shows the number of the period you are in. There are 12 periods in each Round. The second Round starts with period 13 and the third Round starts at period 25.

Remaining time (measured in seconds)

This shows the time remaining in the period in seconds. Each period lasts 60 seconds so the timer counts down from 60 seconds to 0 seconds.

Money

The number of cents that you have available for trading.

Shares

The number of units of stock that you currently own.

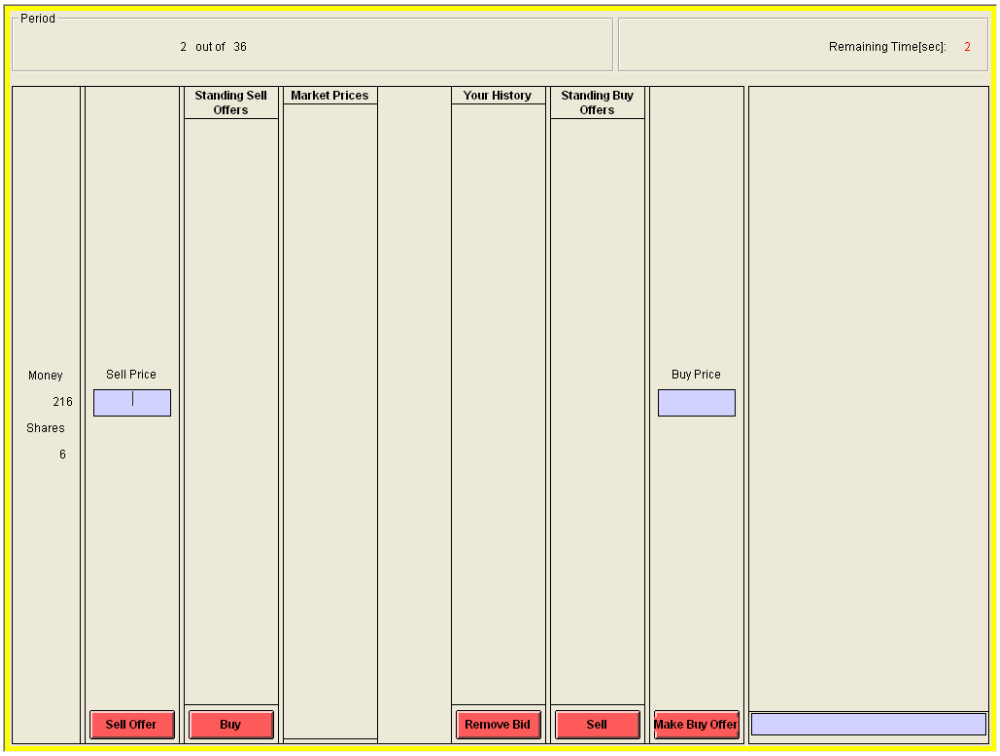
To buy and sell stock you use the blue and red boxes, taking note of the 'Standing Sell Offers' and 'Standing Buy Offers' columns

Standing Sell Offers: Shows all of the stocks that are available for purchase in descending order with the lowest price at the bottom.

Standing Buy Offers: Shows all offers to buy stocks in ascending order with the highest price at the bottom.

Market Prices: Shows the history of the current trading period by listing all of the prices that stocks have been bought or sold for. These prices may not be available for trading.

Your History: Shows all the sell and buy offers you have made in this session.



You can sell a stock two ways: by specifying a sell price and releasing it to the market, or by selling directly to a buyer with an offer in the market

Sell Price: Type the amount, in cents, that you are willing to sell a unit of stock

The amount you type in the **Sell Price** box is your offer to sell one unit of stock at that price

Sell Offer: Pushing this red button releases your offer to the market. Your offer will now be listed in the **Standing Sell Offers** and **Your History** columns

The sale will not be complete until your sell offer is accepted by a buyer.

Sell: Allows you to respond to an offer in the market and make an immediate sale.

Highlight the amount you wish to sell the stock for from the offers available in the **Standing Buy Offers**

Press the **Sell** button to complete the sale

You can buy a stock in two ways: by specifying a buy price and then releasing it to the market to attract a seller, or by buying it directly from a seller with an offer in the market.

Remove Bid: Press the "Remove Bid" button if you would like to remove the sell or buy offers you have made.

2.4. Value of Stocks Based on Holding Values

You can use the table in Section 4 to help you make decisions. There are 5 columns in the table:

Column1 – *Ending Period*: indicates the last trading period of the trading session.

Column 2 – *Current Period*: indicates the period for which the average holding value is calculated.

Column 3 – *Periods Remaining*: gives the number of holding periods from the *Current Period* until the end of the trading session.

Column 4 – *Average Dividend Value per Period*: gives the average (or expected) amount of the dividend that will be paid in that period for each unit of stock you hold. (Please note, although the actual dividend will either be 0 or 18 cents, the average for each period remains the same at 9 cents.)

Column 5 – *Average Holding Value/unit of stock*: gives the expected total dividend for each unit of stock in the periods remaining. That is, if you held one unit of stock and did not sell it in the periods remaining, on average the total dividends you would receive are listed in column 5. The number in column 5 is calculated by multiplying the numbers in columns 3 and 4.

For example, suppose that there is trading in the last 4 periods in a session. Since the dividend paid on a unit of stock has a 50% chance of being 0 and a 50% chance of being 18, the average dividend s therefore 9 cents for each unit of stock (as shown in column 4). If you hold a unit of stock for 4 periods, the expected total dividend for that single unit of stock over the 4 periods will be 4*9 = 36.

Final Period	***Current Period***	***Periods Remaining*** **x**	***Average Dividend per = Period***	***Average Holding Value/unit of stock***
12	**1**	**12**	**9**	**108**
12	**2**	**11**	**9**	**99**
12	**3**	**10**	**9**	**90**
12	**4**	**9**	**9**	**81**
12	**5**	**8**	**9**	**72**
12	**6**	**7**	**9**	**63**
12	**7**	**6**	**9**	**54**
12	**8**	**5**	**9**	**45**
12	**9**	**4**	**9**	**36**
12	**10**	**3**	**9**	**27**
12	**11**	**2**	**9**	**18**
12	**12**	**1**	**9**	**9**

2.5. z-Tree Inter-Round Trading Questions and Associated Variables

BEFORE QUESTIONS

1) How well did you understand the instructions?
2) How do you think you will perform in terms of earnings in the next trading session? (7 is the highest level of earnings; 4 is the average earnings; 1 is the lowest level of earnings)

INTERIM QUESTIONS:

1) How do you think you performed in terms of earnings in the trading session you just completed?

2) What do you think determined your performance? (1 is the minimum level and 7 is the maximum level)

a) Luck

b) Your talent

c) Your character

d) Your calculations

e) Your strategies

f) Your mistakes

g) Mistakes of others

h) Strategies of others

3) What do you think just happened in the last trading session? (1 = strongly disagree; 7 = strongly agree)

a) Prices went higher than I expected

b) Prices went lower than I expected

c) Prices fluctuated more than I expected

d) Prices were about right

4) What strategy, if any, have you tried to use during the last session?

a) Followed what others were doing

b) No strategies used

c) Did not understand the rules of the game

d) Did not understand what I was doing

5) What do you think other participants were doing (1 = strongly disagree; 7 = strongly agree)

a) Selling too high

b) Selling too low

c) Buying too high

d) Buying too low

e) I don’t know

6) Please rate your feelings in the last trading session according to these categories (1 = strongly disagree; 7 = strongly agree)

a) Satisfied

b) Excited

c) Angry

d) Confused

7) How do you think you will perform in terms of earnings in the next trading session (7 is the highest level of earnings; 4 is the average earnings, 1 is the lowest level of earnings)

AFTER QUESTIONS:

1) How would you rate your stress level during each session of trading? (7 being the highest level of stress)

a. Round 1 stress level
b. Round 2 stress level
c. Round 3 stress level

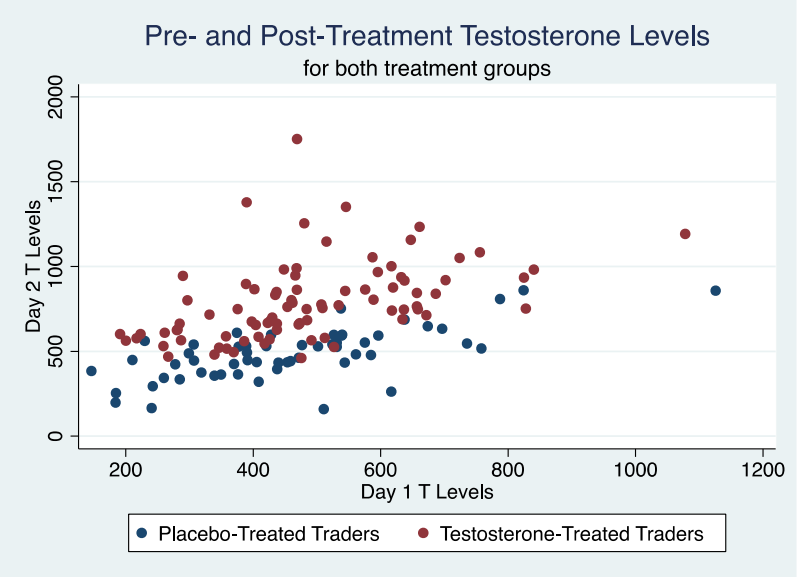
2) How many times have you participated in an experiment like this involving market trading?

3) Which treatment do you think you received? T or P?

4) How certain are you about this? (with one being don't know and 7 being absolutely certain)

Section 3. Variable Definitions, Robustness Checks and Supplementary Analysis

Figure A.1. Testosterone Levels on Both Days for Every Trader



Notes. Testosterone measurements on day 1 and day 2 show placebo-treated traders did not experience significant changes in testosterone levels, whereas traders who received testosterone exogenously showed, on average, significantly increased levels (Figure 2 in main body). Despite average differences between testosterone and placebo groups, some individual testosterone-treated traders did not experience significant increases in their testosterone levels after administration. This outcome was likely caused by their noncompliance with clear and repeated instructions to avoid showering or engaging vigorous exercise following gel administration.

Table A.1. Bubble Characteristic Measures

Measure name	*Description*	*Equation*
Amplitude	Trough-to-peak change in market asset value relative to fundamental value within a 12-period round	$\frac{\max\{(P_t - f_t)}{E} - \frac{\min\{(P_t - f_t)}{E}$
Average Bias	By how much do prices deviate from fundamental value, either positive or negative over a 12-period Round	$\frac{1}{N}\sum_{p=1}^{N}(MedianP_p - FV_p)$
Duration	How long do prices persist above fundamental value	$\max\{m : P_t - f_t < P_{t+1} - f_{t+1} < ... < P_{t+m} - f_{t+m}\}$
Market Value Amplitude	Normalized market value of trade; period amplitude weighted by volume of trade	$\max\{[P_t - f_t / E]V_t : t = 1,...,12\}$
Normalized absolute price deviation	Sum of all absolute deviations of transacted prices from fundamental value divided by shares outstanding	$\sum \left\lvert \frac{P_{i,t} - FV_t}{shares} \right\rvert$
Relative Deviation	Average deviation from fundamental value normalized by fundamental value	$\frac{1}{N}\sum_{p=1}^{N}(\overline{P_p} - FV_p)/\lvert \overline{FV} \rvert$
Relative Absolute Deviation	Average level of mispricing, insensitive to direction of mispricing	$\frac{1}{N}\sum_{p=1}^{N}\lvert \overline{P_p} - FV_p \rvert/\lvert \overline{FV} \rvert$
Total Dispersion	Sum of deviation of median prices from fundamental value	$\sum_{p=1}^{N}\lvert MedianP_p - FV_p \rvert$
Turnover	Trading activity in a market; number of assets traded divided by number of assets in the market	$\frac{\sum AssetsTraded}{\sum Assets}$

Notes. This table describes and defines measures of bubble size and attributes used for market level analysis.

Table A.2. Summary of Market Measures

		Round 1		Round 2		Round 3	
Type of Measure	Variable	Placebo	Testosterone	Placebo	Testosterone	Placebo	Testosterone
Bubble Size	Amplitude	0.39	0.85	0.30	0.59	0.21	0.47
		(0.23)	(0.40)	(0.23)	(0.43)	(0.11)	(0.41)
	p > | z |	0.03		0.21		0.14	
	z-score	2.15		1.27		1.46	
	Market value amplitude	2.57	8.76	1.43	4.64	0.91	2.02
		(2.65)	(5.89)	(1.34)	(4.4)	(0.92)	(1.80)
	p > | z |	0.04		0.14		0.17	
	z-score	2.05		1.46		1.37	
	Average Bias	10.54	37.73	5.72	32.45	7.74	15.88
		(14.01)	(26.2)	(8.76)	(34.17)	(13.93)	(23.79)
	p > | z |	0.02		0.20		0.44	
	z-score	2.25		1.27		0.78	
	Normalized Price Deviation	0.08	0.38	0.07	0.21	0.07	0.13
		(0.11)	(0.27)	(0.09)	(0.22)	(0.13)	(0.21)
	p > | z |	0.03		0.20		0.44	
	z-score	2.25		1.27		0.78	
	Relative Absolute Deviation	0.26	0.74	0.10	0.59	0.09	0.31
		(0.18)	(0.23)	(0.12)	(0.32)	(0.22)	(0.38)
	p > | z |	0.04		0.20		0.33	
	z-score	2.05		1.27		0.98	
	Relative Deviation	9.40	40.74	2.30	33.38	1.62	15.97
		(8.54)	(14.17)	(20.47)	(5.81)	(3.42)	(24.57)
	p > | z |	0.02		0.14		0.28	
	z-score	2.34		1.46		1.07	
	Total Dispersion	16.99	41.99	9.56	34.05	9.83	18.15
		(12.6)	(26.99)	(6.86)	(32.7)	(13.27)	(22.88)
	p > | z |	0.05		0.21		0.28	
	z-score	1.95		1.27		1.07	
Bubble lifespan	Duration	4.00	5.00	2.86	4.80	2.29	4.00
		(1.51)	(2.24)	(0.99)	(2.71)	(0.7)	(2.49)
	p > | z |	0.43		0.19		0.04	
	z-score	0.80		1.30		2.05	
Volume of trades	Turnover	2.88	2.94	2.61	2.52	2.48	2.01
		(0.86)	(1.03)	(0.56)	(0.85)	(0.58)	(0.62)

	p > | z |	0.77		0.5		0.12	
	z-score	0.29		0.68		1.56	
Rate of change	Leadup	5.59	17.39	3.87	10.24	1.73	3.75
		(3.87)	(16.17)	(4.73)	(15.7)	(1.27)	(2.62)
	p > | z |	0.04		0.85		0.17	
	z-score	2.05		0.20		1.37	
Price variability	Price-FV Variance	147.52	784.87	97.17	416.68	42.19	307.68
		(184.14)	(603.05)	(115.24)	(355.87)	(49.85)	(522.39)
	p > | z |	0.06		0.63		0.92	
	z-score	1.85		0.49		0.10	

Notes. Using standard measures from the literature on bubble size (i.e., amplitude and market value amplitude, or MVA), lifespan (duration), and volume (turnover) of trade, we test for differences between the testosterone and placebo markets (standard errors shown below respective means in parentheses; see Table A.1. for definitions.).

We find significant differences in bubble size in the first round using non-parametric *t*-tests (2-tailed Mann-Whitney Test, due to small sample size), but similar duration and turnover. Turnover represents shares traded, yet does not capture the bid and ask prices or volume, which differ between groups and contain valuable information regarding price paths and beliefs.

Table A.3. Regression of Market Measures with Dummy Variables for Cohort Size

	Amplitude	MVA	Duration	Turnover
Treatment	0.718***	6.364***	2.519**	–0.0321
	(0.103)	(1.180)	(1.137)	(0.0230)
Round = 2	–0.188**	–2.891***	–0.588	–0.0294
	(0.0819)	(1.030)	(0.730)	(0.0232)
Round = 3	–0.299***	–4.646***	–1.294*	–0.0586**
	(0.0863)	(1.096)	(0.723)	(0.0226)
Size = 6	0.850***	7.234***	2.056	0.0242
	(0.163)	(1.595)	(1.698)	(0.0288)
Size = 7	0.596***	5.795***	1.176	0.00361
	(0.154)	(1.368)	(1.342)	(0.0198)
Size = 8	–0.184	0.0401	–2.000*	–0.00856
	(0.136)	(1.583)	(1.037)	(0.0198)
Size = 9	0.440**	6.969***	1.500	0.0677
	(0.176)	(2.047)	(1.234)	(0.0437)
Size = 10	0.770***	10.09***	2.259	–0.0187
	(0.188)	(2.558)	(1.386)	(0.0177)
Size = 11	0.194	2.380	1.000	0.0427
	(0.166)	(1.746)	(1.414)	(0.0295)
Size = 12	–0.00315	3.404*	0.667	0.116***
	(0.146)	(1.829)	(1.337)	(0.0412)
Size = 14	0.742***	10.72***	2.519	0.0320
	(0.162)	(1.774)	(1.511)	(0.0249)
Constant	–0.290	–3.577*	1.776	0.237***
	(0.180)	(1.809)	(1.633)	(0.0288)
N	51	51	51	51
R^2	0.707	0.681	0.345	0.367

Notes. OLS regression of market measures are shown as dependent variables; and a binary variable ("Treatment") is shown for testosterone (1) and placebo (0); dummy variables are shown for rounds (Round = 1 omitted); and the number of traders in cohort (Size) is included as a continuous variable. Each session produced three observations, one for each round of trading (*N* = 51). Results show testosterone-treated groups had larger bubbles (i.e., periods of asset prices exceeding the asset's fundamental value) while controlling for cohort size as a dummy variable (excluding size = 5).

Robust standard errors are shown in parentheses.

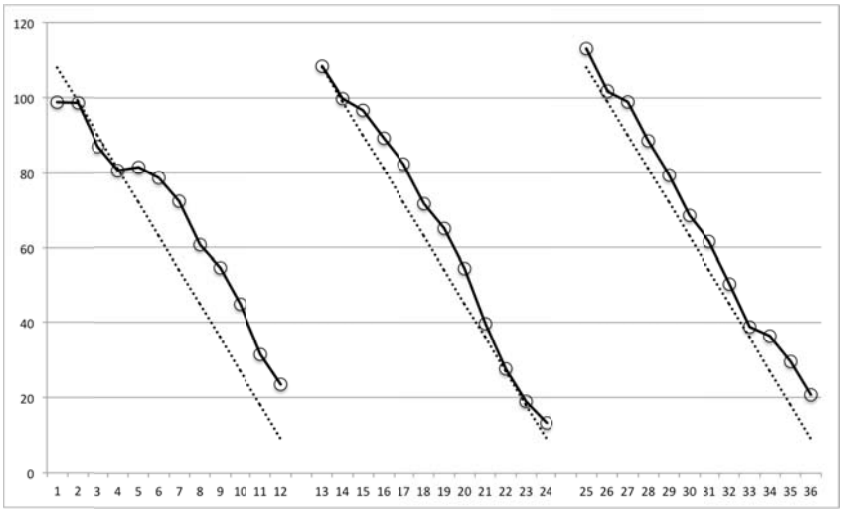
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A.4. Variable definitions of Individual-Level Analysis

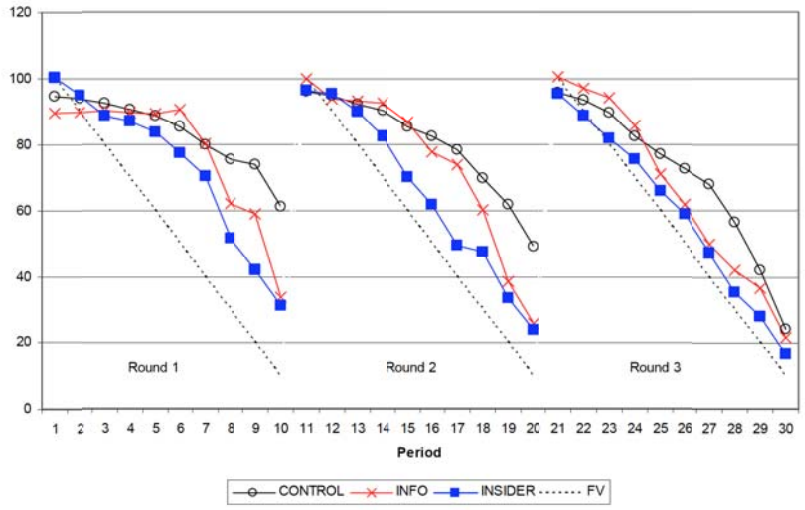
Measure name	Description
Average Buy	Average price of bids posted
Average Sell	Average price of offers posted
Priceup	A binary variable of change of prices between consecutive periods: 1 for increase, 0 for no increase
Buying Offer Turnover	Number of buying offers divided by outstanding shares
Selling Offer Turnover	Number of selling offers divided by outstanding shares
Turnover Difference	Difference between number of Buying Offer Turnover and Selling Offer Turnover within a period, which is a measure of excess bids in the market
Pay	A variable that counts the number of consecutive periods during which a dividend of $0.18 was paid.
No Pay	A variable that counts the number of consecutive periods during which a dividend of $0.00 was paid.

Figure A.2. Comparison of Overpricing between Placebo Sessions to Similar Published Experimental Markets

Panel A. Average Prices and Fundamental Value of Our Placebo Sessions



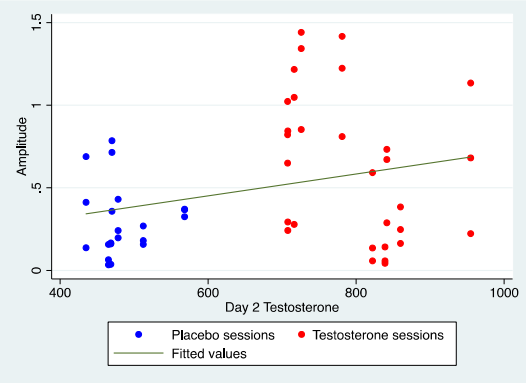
Panel B. Average Prices and Fundament Value of Sutter et al. (2012)



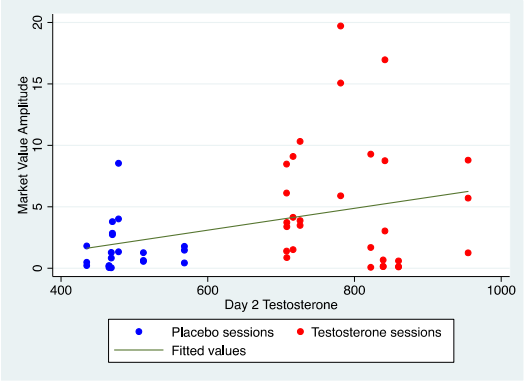
Notes. The top panel shows assets' average prices (black line with black open circles) for all trading sessions across three rounds of trading, relative to the assets' fundamental values (straight dashed line). The lower panel depicts assets' average prices and fundamental values for markets in the 2009 version of Sutter, Huber and Kirchler (2012). The "control" market (black line with black open circles) represents markets in which traders do not know the realization of the dividend during the period they are trading (which is remarkably similar to our experiment) in 12 markets. It is apparent that our placebo markets exhibit lower overpricing than the comparable markets in Sutter et al. (2012).

Figure A.3. Relationship between Testosterone Levels and Overpricing

Panel A



Panel B



Notes. Panel A shows the relationship between day 2 testosterone and amplitude. Panel B shows the relationship between day 2 testosterone and market value amplitude. Both are graphed for all traders. The straight lines represent linear fit.

Table A.5 Studies That Focus on Trader Traits or the Effect of States on Experimental Markets

	Variable of interest	Groups	Total number of traders	Traders per market	Amplitude	Average bias	Normalized deviation	Duration (boom)	Turnover	Rounds	Periods	Dividend range
This study	*Testosterone*	*Placebo*	56	5 to 15	0.38	10.5	0.08	4.0	2.9	3	12	0, 18
		Testosterone	84		0.85	37.7	0.38	5.0	2.9			
Eckel & Füllbrunn (2015)	*Gender*	*Male*	54	9	*na*	74.12	*na*	10.67	9.77	1	15	0, 8, 24, 60
		Female	54			–25.71		6.67	14.28			
Janssen et al. (2015)	*Tendency to speculate*	*Low*	39	9 or 10	0.27	48.2	221.0	*na*	4.3	1	15	0, 8, 24, 60
		Medium	39		0.42	84.7	420.1		6.1			
		High	39		0.63	132.9	1252.6		9.1			
Lahav & Meer (2012)	*Emotion*	*Neutral*	18	9	1.30	*na*	3.32	*na*	1.17	1	15	0, 0.5, 1.0, 1.5, 2.0
		Positive	18		2.85		8.23		1.26			
Michailova & Schmidt (2011)	*Overconfidence*	*Rational*	30	6	0.98	*na*	0.49	*na*	*na*	1	15	0, 0.8, 2.8, 6.0
		Overconfident	30		2.29		2.24					

Notes. We report measures from the first round of trading to provide consistent comparability with the other studies in the table. Table A.2 above reports measures for all 3 rounds.

na = measure not used in manuscript

Table A.6. Logit Regressions by Round Testing for Treatment Effect on Bidding Type

	Round 1		Round 2		Round 3[a]	
	Marginal Effect	SE	Marginal Effect	SE	Marginal Effect	SE
Treatment	0.085*	0.05	0.082*	0.05	–0.056	0.05
Delta Price	0.00003**	0.00	–0.00	0.00	0.00	0.00
FV-Price	–0.00	0.00	–0.00	0.00	0.00	0.00
Prepeak	–0.01	0.02	0.05***	0.01	0.02	0.02
Postpeak	–0.01	0.01	–0.01***	0.00	–0.014***	0.00
N	1310		1301		1155	
LL	–800.97		–708.51		–571.03	
Pseudo R^2	0.016		0.044		0.024	

Notes. This table reports marginal effects for logistic regressions with each bid as an observation. The dependent variable is the bidding type (1 = momentum bid, 0 = fundamental bid). Independent variables include a binary variable for Treatment (1 = Testosterone, 0 = Placebo), and its interaction terms with price change from period t − 1 to period t (Delta – Price), fundamental value minus average trading price in period t − 1 (FV – Price), the number of periods prior to price peak (Prepeak), and number of periods after price peak (Postpeak), respectively.
Standard errors are clustered at the individual level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

[a] Round 3 data are estimated at Prepeak = 0 because round 3 had no peaks in the placebo group.

Table A.7. Influence on Overpricing in Relation to Price Peak

	Pre-peak		Post-peak	
	Placebo	Testosterone	Placebo	Testosterone
Ask Volume	–6.005	6.631	–7.494	9.797
	(5.074)	(8.134)	(8.323)	(6.427)
Bid Volume	–9.912*	20.74**	–23.11***	8.618
	(5.100)	(8.568)	(7.264)	(7.891)
Average Ask Price	0.0225	–0.00392	–0.00458	0.0112
	(0.0152)	(0.00916)	(0.0130)	(0.00740)
Average Bid Price	0.137***	0.698***	0.369***	0.645***
	(0.0477)	(0.0675)	(0.0864)	(0.0619)
Round = 1	–7.757**	9.660*	12.46**	25.56***
	(3.289)	(5.405)	(4.834)	(5.813)
Round = 2	–3.817	2.847	6.829	14.37**
	(3.048)	(5.298)	(4.571)	(5.681)
Size	0.176	1.039	–3.150***	–1.396
	(0.461)	0.967)	(0.767)	(1.023)
Constant	4.017	–56.16***	37.20***	–17.01
	(6.507)	(10.89)	(10.42)	(10.92)
Observations	157	200	94	158
R^2	0.150	0.446	0.381	0.542

Notes. This regression shows differences in the effects of bid and ask prices and of volume on the asset price before and after peak price, while controlling for round, number of traders in the market, and bid and sell prices.
OLS standard errors are shown in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A.8. Correlations between Hormones and Earnings Percentile Rank

	Earnings		Earning Percentile Rank		Overconfidence	
	Placebo	Testosterone	Placebo	Testosterone	Placebo	Testosterone
Day 2 DHT levels	0.015	0.250	0.102	0.255	0.087	–0.047
p-value	0.912	0.022	0.455	0.019	0.523	0.674
t-statistic	0.111	2.341	0.752	2.389	0.642	–0.422
Day 2 Testosterone levels	–0.071	0.200	–0.074	0.193	0.021	–0.084
p-value	0.602	0.068	0.588	0.079	0.876	0.449
t-statistic	–0.525	1.849	–0.545	1.778	0.157	–0.761
% change in DHT	–0.018	0.064	0.114	0.065	0.066	–0.005
p-value	0.896	0.578	0.402	0.572	0.630	0.964
t-statistic	–0.131	0.558	0.845	0.567	0.485	–0.046
% change in T	–0.065	0.063	–0.023	0.065	–0.096	0.029
p-value	0.632	0.580	0.868	0.570	0.482	0.800
t-statistic	–0.391	0.557	–0.168	0.571	–0.709	0.255
Absolute change in DHT	–0.059	0.193	0.064	0.213	0.081	–0.021
p-value	0.669	0.089	0.641	0.059	0.555	0.857
t-statistic	–0.431	1.723	0.469	1.914	0.594	–0.181
Absolute change in T	–0.053	0.113	0.014	0.128	–0.104	–0.006
p-value	0.697	0.323	0.918	0.263	0.446	0.960
t-statistic	–0.391	0.994	0.104	1.128	–0.768	–0.050

Notes. *Post hoc* (uncorrected for multiple comparisons) correlations are shown between testosterone (T) or dihydrotestosterone (DHT) levels and changes and trading performance, as measured in percentile rankings for testosterone and placebo groups separately (*p*-values are shown below the correlation coefficient), and overconfidence is measured by the difference between the self-evaluated percentile ranking from surveys and the actual percentile ranking. Testosterone $N = 84$, placebo $N = 56$. None of the significant correlations survive Bonferroni correction for multiple hypotheses testing.

Table A.9. Effects of Androgens on Earnings: OLS Regressions with Percentile Rank as the Dependent Variable

	Testosterone-treated Cohorts			Placebo-treated Cohorts			
Model	(1)	(2)	(3)	(1)	(2)	(3)	All Traders
Day 2 Testosterone		0.0167	–0.00385		–0.0139	–0.0413	–0.0153
		(0.0151)	(0.0175)		(0.0266)	(0.0341)	(0.0149)
% Change Testosterone		6.058	8.854		–0.749	–4.964	4.501
		(6.480)	(6.690)		(9.861)	(11.06)	(5.445)
Cohort *n*	0.596	1.289	1.248	0.655	0.574	0.639	0.725
	(1.505)	(1.596)	(1.595)	(1.224)	(1.235)	(1.227)	(0.956)
Day 2 DHT	0.153**		0.169**	0.142		0.353	0.159**
	(0.0635)		(0.0750)	(0.211)		(0.274)	(0.0698)
% Change DHT	–2.298		–4.023	10.2		12.64	–4.828
	(4.025)		(4.253)	(12.84)		(14.54)	(3.652)
Constant	77.76***	84.53***	85.97***	71.46***	54.57***	61.90***	65.31***
	(15.74)	(20.24)	(19.98)	(16.13)	(17.42)	(17.86)	(11.39)
Observations	84	84	84	56	56	56	140
R^2	0.070	0.031	0.091	0.027	0.010	0.061	0.045

Notes. Regressions are shown that measure the effects of testosterone (T) and dihydrotestosterone (DHT) on the day of trading, the percent change both from day 1 to day 2 (% change), and in the number of traders in the trading session (Cohort n) on percentile ranking of earnings (i.e., a higher number means higher percentile ranking) separately by condition. We find DHT positively predicts higher earnings among testosterone-treated cohorts. Standard errors are shown in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A.10.a. Pre-trading Survey Questions about Comprehension and Performance Expectations (Testosterone = T, Placebo = P)

	Overall		Round 1		Round 2		Round 3	
	P	T	P	T	P	T	P	T
How well did you understand the instructions?								
	5.45	5.29						
	(0.16)	(0.13)						
p-value	0.44							
t-statistic	0.77							
How do you think you will perform in terms of earnings in the next trading session?								
	4.83	4.60	4.93	4.56	4.82	4.71	4.57	4.64
	(0.10)	(0.12)	(0.15)	(0.12)	(0.13)	(0.12)	(0.20)	(0.13)
p-value	0.06		0.06		0.55		0.76	
t-statistic	1.90		1.89		0.60		0.31	

Notes. Two-tailed *p*-values are shown for testing whether testosterone (T) scores are greater than placebo (P) scores. Standard errors are shown are shown in parentheses below means. Overall DF = 418, per-round = 138.

Table A.10.b. Trading Survey Questions Regarding Performance and Reasons Thereof Following Each Round of Trading (Testosterone = T, Placebo = P)

	Overall		Round 1		Round 2		Round 3	
	P	T	P	T	P	T	P	T
How do you think you performed in terms of earnings in the trading session you just completed?								
	4.3	4.0	4.2	4.0	4.12	3.7	4.5	4.4
	(0.12)	(0.10)	(0.20)	(0.18)	(0.23)	(0.16)	(0.19)	(0.18)
p-value	0.13		0.50		0.11		0.74	
t-statistic	1.50		0.78		1.62		0.33	
What do you think determined your performance? (1 is the minimum level and 7 is the maximum level)								
Luck	4.4	4.0	3.9	3.8	3.3	3.9	4.9	4.3
	(0.13)	(0.11)	(0.23)	(0.19)	(0.24)	(0.19)	(0.17)	(0.21)
p-value	0.03		0.68		0.20		0.04	
t-statistic	2.15		0.42		1.30		2.08	
Talent	4.2	4.4	4.1	4.2	4.3	4.6	4.1	4.7
	(0.12)	(0.10)	(0.20)	(0.18)	(0.21)	(0.17)	(0.2)	(0.17)
p-value	0.07		0.98		0.49		0.02	
t-statistic	1.80		0.15		0.69		2.32	
Character	3.4	3.6	3.4	3.3	3.5	3.7	3.3	3.8
	(0.12)	(0.12)	(0.22)	(0.20)	(0.22)	(0.19)	(0.21)	(0.21)
p-value	0.25		0.81		0.52		0.12	
t-statistic	1.16		0.23		0.65		1.57	
Calculations	4.4	4.6	4.6	4.4	4.3	4.5	4.4	4.7
	(0.12)	(0.11)	(0.21)	(0.21)	(0.23)	(0.17)	(0.19)	(0.17)
p-value	0.36		0.77		0.49		0.20	
t-statistic	0.91		0.29		0.69		1.30	
Self strategies	4.8	5.1	5.0	4.9	4.7	5.0	4.8	5.3
	(0.11)	(0.09)	(0.18)	(0.18)	(0.21)	(0.15)	(0.18)	(0.14)
p-value	0.09		0.81		0.29		0.02	
t-statistic	1.7		0.24		1.05		2.33	
Self mistakes	4.1	4.4	4.4	4.7	3.9	4.6	4.0	3.9
	(0.13)	(0.11)	(0.21)	(0.19)	(0.24)	(0.21)	(0.23)	(0.19)
p-value	0.17		0.39		0.07		0.72	
t-statistic	1.39		0.87		1.82		0.36	
Other mistakes	4.6	4.6	5.1	5.1	4.4	4.7	4.2	4.3
	(0.14)	(0.11)	(0.22)	(0.17)	(0.26)	(0.20)	(0.22)	(0.20)
p-value	0.96		0.89		0.90		0.85	
t-statistic	0.04		0.14		0.13		0.19	
Other strategies	4.4	4.7	4.6	5.0	4.2	4.6	4.3	4.7
	(0.11)	(0.10)	(0.16)	(0.16)	(0.21)	(0.19)	(0.20)	(0.18)
	0.01		0.11		0.26		0.12	
	2.45		1.60		1.17		1.55	

Notes. Two-tailed p-values tested whether testosterone (T) scores were greater than placebo (P) scores. Standard errors are shown are shown in parentheses below means. Overall DF = 418, per-round = 138.

Table A.10.c. Trading Survey Questions Regarding Price Expectations (Testosterone = T, Placebo = P)

	Overall		Round 1		Round 2		Round 3	
	P	T	P	T	P	T	P	T
What do you think just happened in the last trading session? (1 = strongly disagree; 7 = strongly agree)								
Prices went higher than I expected.	4.0	3.7	4.1	4.4	0.38	3.5	3.91	3.0
	(0.14)	(0.12)	(0.27)	(0.21)	(0.24)	(0.19)	(0.24)	(0.19)
p-value	0.11		0.38		0.33		0.00	
t-statistic	1.58		0.88		0.97		2.88	
Prices went lower than I expected.	3.6	4.2	3.4	3.7	3.8	4.4	3.6	4.5
	(0.14)	0.13)	(0.24)	(0.23)	(0.24)	(0.21)	(0.25)	(0.22)
p-value	0.00		0.31		0.04		0.01	
t-statistic	3.2		1.02		2.05		2.58	
Prices fluctuated more than I expected.	3.7	3.8	3.7	3.8	3.7	3.9	3.7	3.8
	(0.12)	0.11)	(0.21)	(0.19)	(0.22)	(0.18)	(0.22)	(0.19)
p-value	0.30		0.62		0.40		0.65	
t-statistic	1.04		0.5		0.84		0.45	
Prices were about right.	3.7	3.6	3.5	3.3	3.9	3.6	3.8	3.9
	(0.12)	(0.11)	(0.18)	0.19)	(0.24)	(0.19)	(0.21)	(0.20)
p-value	0.47		0.53		0.33		0.72	
t-statistic	0.72		0.63		0.98		0.36	

Notes. Two-tailed *p*-values tested whether testosterone (T) scores were greater than placebo (P) scores. Standard errors shown are shown in parentheses below means. Overall DF = 418, per-round = 138.

Table A.10.d. Trading Survey Questions Regarding Strategy in Preceding Round of Trading (Testosterone = T, Placebo = P)

	Overall		Round 1		Round 2		Round 3	
	P	T	P	T	P	T	P	T
What strategy, if any, have you tried to use during the last session?								
Followed what others were doing	3.1	3.1	3.2	3.0	3.0	3.2	3.0	3.1
	(0.14)	(0.12)	(0.25)	(0.2)	(0.23)	(0.20)	(0.22)	(0.21)
p-value	0.97		0.45		0.66		0.70	
t-statistic	0.04		0.76		0.45		0.39	
No strategies used	2.3	2.4	2.2	2.5	2.4	2.5	2.4	2.3
	(0.12)	(0.11)	(0.20)	(0.21)	(0.22)	0.18)	(0.21)	(0.18)
p-value	0.61		0.38		0.78		0.74	
t-statistic	0.51		0.89		0.27		0.33	
Did not understand the rules of the game	2.1	2.0	2.5	2.4	2.1	1.9	1.7	1.8
	(0.20)	(0.14)	(0.26)	(0.18)	(0.22)	0.13)	(0.17)	(0.15)
p-value	0.51		0.33		0.38		0.61	
t-statistic	0.66		0.99		0.88		0.51	
Did not understand what I was doing	2.3	2.1	2.7	2.4	2.2	2.2	2.0	1.9
	(0.14)	(0.10)	(0.26)	(0.19)	(0.23)	(0.16)	(0.23)	(0.17)
p-value	0.34		0.33		0.86		0.63	
t-statistic	0.96		0.97		0.17		0.47	

Notes. Two-tailed *p*-values tested whether testosterone (T) scores were greater than placebo (P) scores. Standard errors are shown in parentheses below means. Overall DF = 418, per-round = 138.

Table A.10.e. Trading Survey Questions Regarding Prices in Preceding Round of Trading (Testosterone = T, Placebo = P)

	Overall		Round 1		Round 2		Round 3	
	P	T	P	T	P	T	P	T
What do you think other participants were doing? (1 = strongly disagree; 7 = strongly agree)								
Buying too high	4.4	4.2	4.7	4.5	4.2	4.2	4.4	4.0
	(0.14)	(0.12)	(0.24)	(0.21)	(0.24)	(0.21)	(0.23)	(0.20)
p-value	0.31		0.68		0.94		0.20	
t-statistic	1.01		0.42		0.07		1.30	
Others buying too low	3.2	3.7	3.0	3.4	3.4	3.9	3.3	3.8
	(0.13)	(0.12)	(0.22)	(0.21)	(0.23)	(0.22)	(0.21)	(0.20)
p-value	0.00		0.19		0.18		0.05	
t-statistic	2.65		1.31		1.34		1.96	
Others selling too high	4.5	4.0	4.3	4.2	4.6	3.9	4.5	3.6
	(0.14)	(0.12)	(0.26)	(0.22)	(0.24)	(0.21)	(0.23)	(0.20)
p-value	0.00		0.66		0.04		0.01	
t-statistic	3.02		0.44		2.09		2.82	
Others selling too low	3.2	4.0	3.3	3.9	3.4	4.0	3.0	4.1
	(0.14)	(0.12)	(0.25)	(0.21)	(0.25)	(0.21)	(0.20)	(0.20)
p-value	0.00		0.09		0.11		0.00	
t-statistic	4.03		1.72		1.61		3.65	
I don't know	3.2	3.2	3.4	3.5	3.2	3.2	3.0	2.9
	(0.15)	(0.12)	(0.26)	(0.23)	(0.26)	(0.21)	(0.26)	(0.20)
p-value	0.91		0.83		0.86		0.80	
t-statistic	0.11		0.22		0.18		0.26	

Note. Two-tailed *p*-values tested whether testosterone (T) scores were greater than placebo (P) scores. Standard errors are shown in parentheses below means. Overall DF = 418, per-round = 138.

Table A.10.f. Trading Survey Questions Regarding Affect in Preceding Round of Trading (Testosterone = T, Placebo = P)

	Overall		Round 1		Round 2		Round 3	
	P	T	P	T	P	T	P	T
Please rate your feelings in the last trading session according to these categories (1 = strongly disagree; 7 = strongly agree)								
Satisfied	4.3	4.1	4.4	4.2	4.1	3.8	4.4	4.4
	(0.15)	(0.11)	(0.22)	(0.19)	(0.24)	(0.20)	(0.19)	(0.18)
p-value	0.32		0.52		0.28		0.95	
t-statistic	1.00		0.65		1.10		0.06	
Excited	4.4	4.3	4.9	4.8	4.3	4.1	4.1	4.1
	(0.12)	(0.10)	(0.19)	(0.17)	(0.21)	(0.18)	(0.2)	(0.19)
p-value	0.44		0.58		0.48		0.93	
t-statistic	0.76		0.56		0.71		0.10	
Angry	2.6	2.8	2.6	2.6	2.7	3.1	1.5	2.5
	(0.12)	(0.11)	(0.19)	(0.16)	(0.22)	(0.20)	(0.21)	(0.19)
p-value	0.14		0.19		0.21		0.99	
t-statistic	1.47		1.33		1.25		0.01	
Confused	2.7	2.9	3.2	3.5	2.7	3.0	2.2	2.4
	(0.14)	(0.12)	(0.21)	(0.25)	(0.22)	(0.21)	(0.23)	(0.20)
p-value	0.21		0.48		0.41		0.51	
t-statistic	1.25		0.71		0.83		0.67	

Note. Two-tailed p-values tested whether testosterone (T) scores were greater than placebo (P) scores. Standard errors are shown in parentheses below means. Overall DF = 418, per-round = 138.

Table A.10.g. Post-trading Survey Questions (testosterone = T, placebo = P)

	Overall		Round 1		Round 2		Round 3	
	P	T	P	T	P	T	P	T
Questions following trading:								
How would you rate your stress level during each session of trading? (7 being the highest level of stress)								
			4.27	3.61	3.79	3.77	3.27	–3.31
			(0.24)	(0.20)	(0.21)	–(0.17)	(0.23)	(0.18)
p-value			0.04		0.97		0.89	
t-statistic			2.12		0.044		0.14	
How many times have you participated in an experiment like this involving market trading?								
	1.32	1.26						
	(0.11)	(0.09)						
p-value	0.68							
t-statistic	0.41							
Which treatment do you think you received? T or P?								
	0.27	0.30						
	(0.06)	(0.05)						
p-value	0.70							
z-statistic	0.38							
How certain are you about this? (with one being don't know and 7 being absolutely certain)								
	3.36	2.76						
	(0.26)	(0.18)						
p-value	0.065							
t-statistic	–1.87							

Note. Two-tailed p-values tested whether testosterone (T) scores were greater than placebo (P) scores. Standard errors are shown in parentheses below means. Overall DF = 418, per-round = 138.

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