

Second-to-fourth digit ratio predicts success among high-frequency financial traders

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Prenatal androgens have important organizing effects on brain development and future behavior. The second-to-fourth digit length ratio (2D:4D) has been proposed as a marker of these prenatal androgen effects, a relatively longer fourth finger indicating higher prenatal androgen exposure. 2D:4D has been shown to predict success in highly competitive sports. Yet, little is known about the effects of prenatal androgens on an economically influential class of competitive risk taking—trading in the financial world. Here, we report the findings of a study conducted in the City of London in which we sampled 2D:4D from a group of male traders engaged in what is variously called “noise” or “high-frequency” trading. We found that 2D:4D predicted the traders’ long-term profitability as well as the number of years they remained in the business. 2D:4D also predicted the sensitivity of their profitability to increases both in circulating testosterone and in market volatility. Our results suggest that prenatal androgens increase risk preferences and promote more rapid visuomotor scanning and physical reflexes. The success and longevity of traders exposed to high levels of prenatal androgens further suggests that financial markets may select for biological traits rather than rational expectations.

2D:4D | neuro-economics | risk taking | market selection | testosterone

Successful trading in the financial markets requires more than correct beliefs about the value of securities. Traders must also possess confidence enough to place their bets, risk preferences high enough to place bets of meaningful size, and the ability to process information quickly enough to keep one step ahead of competitors. Furthermore, traders engaged in “noise” or “high-frequency” trading require additional skills because their rapid style of trading is a demanding physical activity: they engage in extended periods of vigilance and visuomotor scanning, and they must react quickly to place a trade before other traders arbitrage it away. The physiological demands made on traders raise the possibility that success in the markets depends as much on traders’ biological traits as it does on the truth of their beliefs.

These biological traits may derive in part from traders’ prenatal exposure to androgenic steroids. Prenatal androgens have organizing effects on the developing brain, increasing its later sensitivity to the activational effects of circulating testosterone (1–3). According to both animal and human studies, these effects may include increased confidence (4), risk preferences (5–7), and search persistence (8), as well as heightened vigilance and quickened reaction times (9). A number of surrogate markers have been proposed for measuring the effects of fetal androgens (10), but perhaps the most convenient is the second-to-fourth digit length ratio (2D:4D), a relatively longer fourth finger (i.e., lower 2D:4D) indicating higher fetal androgens (11). Digit ratios have been found to predict performance in competitive sports, such as soccer (12), rugby, basketball (13), and skiing (14), so 2D:4D may also predict the risk preferences and physical speed required for high-frequency trading. We therefore formulated the hypothesis that higher prenatal testosterone exposure would improve

a trader’s performance. Specifically, we predicted that traders with a lower 2D:4D would make greater long-term profits and would remain in the business for a longer period of time.

To test our prediction we recruited 49 male traders from a trading floor in the City of London (15). This floor employed ≈200 traders, of which all but 3 were male. The more successful of these traders earn in excess of £4 million per year. The floor is typical of others in the financial world with respect to its physical layout, the markets traded, and the traders’ average age and income (Fig. 1). The traders on this floor specialize in noise or high-frequency trading: they buy and sell securities, specifically futures contracts, sometimes in sizes of up to £1 billion, but hold their positions for only a few minutes, sometimes mere seconds (16). Other types of traders, such as investors at mutual and pension funds or arbitrageurs at hedge funds and investment banks, take more time to analyze a security’s value and hold their trades for weeks, months, or years. Investors and arbitrageurs try to profit from market trends, whereas high-frequency traders make their money by trading temporary variations around the trend.

We used individual traders’ profit and loss (P&L) statements as the primary measure of their relative performance. Trader P&Ls are recorded continuously by the firm’s back office, so they are free of reporting bias. Traders had equal access to capital and information, and their risk limits were determined by their track records. P&L for this cohort was thus an objective and comparable measure of trading skill and, after profit sharing with the employing firm, determined their individual income. These traders received no salary or year-end bonus, and their P&Ls did not have the benefits of an underlying client business. Consequently, selective pressures act more quickly and insistently on these traders than on investment bankers or fund managers.

For ease of measurement and reproducibility we used 2D:4D as a surrogate measure of prenatal androgen exposure. Support for this measure, according to some researchers, derives from the fact that digit growth and gonadal development are linked by the common influence of *hox* genes (11, 17). Members of the homeobox-containing gene family (e.g., *hoxa* and *hoxd*) are strongly expressed in the genital bud and give rise to the urogenital system; yet, they also pattern limb development and digit growth (18). Indeed, loss-of-function mutations in *HOXA13* result in both shortening of the digits and defects in the urogenital tract (hand–foot–genital syndrome) (19).

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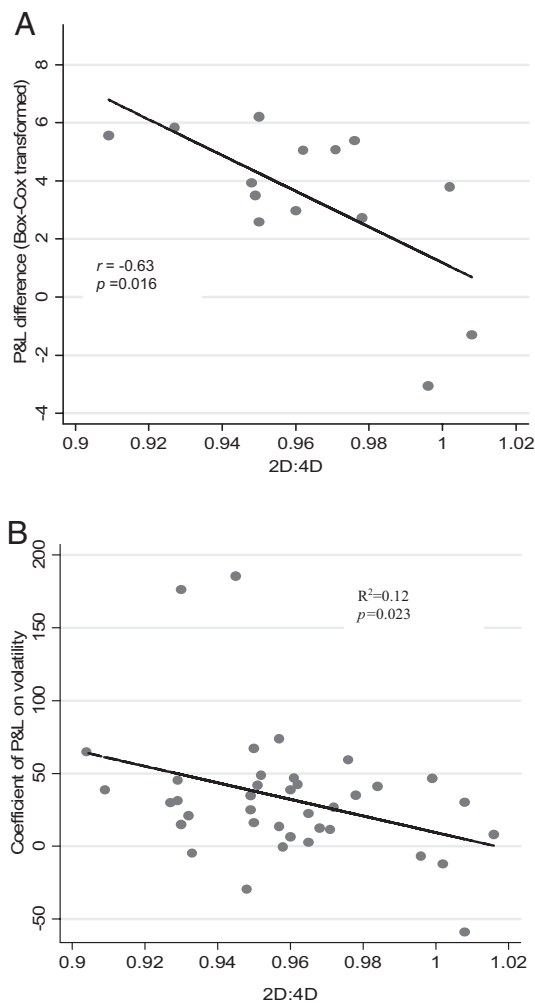


Fig. 3. Circulating testosterone, volatility, and P&L. (A) The difference in each trader's P&L between days of high and low morning testosterone plotted against their 2D:4D. (B) Traders' 2D:4D plotted against the sensitivity of their P&L to changes in volatility. The plot was derived in 2 stages: First, each trader's P&L, recorded over a 20-month period, was regressed against the volatility of the Euribor futures contract over the same period. The slope of the resulting curve gave us a measure of the sensitivity of each trader's P&L to changes in volatility. Second, the slope of each trader's curve was plotted against his 2D:4D. The two outlier data points were handled by robust regression and did not distort the results.

In this second line of analysis, we used the volatility of Euribor (3-month European interbank rates) as a proxy for market volatility. Euribor is one of the core assets traded on this floor, and its variance displayed a high correlation with P&L over a 20-month period averaged from all traders ($R^2 = 0.735$, $P < 0.0005$, $n = 20$). We first estimated a regression coefficient for each trader, which displayed how his P&L responded when Euribor volatility increased or decreased. We next regressed these coefficients against each trader's 2D:4D and found that the regression was significant ($R^2 = 0.12$, $F_{1,36} = 5.61$, $P = 0.023$; Fig. 3B). Regressing these coefficients against experience, on the other hand, did not give a significant result ($b = 12.9$, $P = 0.301$). Put simply, these results show that the lower a trader's 2D:4D, the more money he makes as volatility increases.

Discussion

We have found that digit ratios together with years of training predict a high-frequency trader's long-term P&L. Our model

suggests a roughly even split between the contributions of biology and experience; biology in this case being the organizing effects of prenatal androgens on an individual's body, brain, and behavior. As digit ratios are set early in life, there can be no feedback mechanism of the sort one might find between P&L and circulating testosterone (30); digit ratios predict profitability, not vice versa. Moreover, the correlations we have observed in this cohort between digit ratios and profits hold true over a 20-month period; and the correlations between digit ratios and years of experience hold over many years, in both bull and bear markets, so the survival of low-2D:4D traders does not appear to depend on particular market conditions.

The finding that a marker of prenatal testosterone levels predicts a trader's long-term profitability dovetails with an earlier study, which found that levels of circulating testosterone predict short-term profitability (30). Indeed, 2D:4D gauges the sensitivity of P&L to changes in circulating testosterone. Taken together, these two studies lend support to the organizational/activational hypothesis of steroid action.

Finally, the results of the current study suggest that the traits signaled by 2D:4D are likely to confer the greatest advantage in noise or high-frequency trading, an occupation that requires, in addition to the ability to take risks, heightened vigilance and quick reactions. Our findings may therefore be replicated among amateur day traders, high-frequency traders at other banks, and local traders on the floors of stock and futures exchanges. But the correlation may weaken among traders who require additional skills. Flow traders at the investment banks, for example, engage in high-frequency trading, but they also require an ability to deal with clients and a sales force, and these traders often make the bulk of their P&L from client business rather than pure risk-taking. The correlation could even reverse sign among traders who adopt a more analytical and long-term approach to the markets. For example, arbitrage traders at the investment banks and hedge funds are increasingly hired from the math and science departments of universities, and one study, which looked at average digit ratios in university departments found that faculty from math, science, and engineering exhibited higher, more feminine digit ratios (35). A similar result may well be found among traders with a long-term holding period.

The financial markets are made up of many sectors and types of trading, and each of these may select for different biological traits. But if markets select traders on the basis of their profitability and their occupational preferences (36), then low-2D:4D traders will continue to influence asset prices and equilibria in some of these sectors. Contrary to the assumptions of the rational expectations hypothesis, financial market equilibria may be influenced as much by traders' biological traits as by the truth of their beliefs.

Materials and Methods

Subjects. During recruitment we approached potential subjects on the trading floor and invited them to participate in the study. They were given an introductory note that explained briefly that we were looking at the effects of prenatal testosterone on the shape of their right hand. No information was given about our hypothesis. Interested traders were informed that they would receive a summary of our findings; they were not offered payment. Of the traders asked to participate, all but 3 agreed. Before giving a handprint, all subjects completed a short questionnaire asking their age, years of trading, P&L history, number of older brothers, and whether they had broken the index or ring finger of their right hand. They also signed an informed consent form. All handprints, questionnaire data, and P&L from the bank were coded by an independent laboratory technician in Cambridge, so our analyses were conducted blindly with respect to the identity of the traders. The study was approved by the Ethics Committee of the School of Biological Sciences at the University of Cambridge.

Five of the traders volunteering for the study could not be included because they had broken either the index or ring finger of their right hands. From the remaining 49 subjects, 2 were subsequently excluded because their handprints

were of insufficient quality to be assessed, and 3 were excluded because they received a different compensation package from the other traders, making it difficult to compare their P&Ls (although retaining them in the study left all results significant).

P&L Sampling. During the study some traders left the firm while others joined, so for some traders we had less than 20 months of P&L data, and the dates of their samples varied. Traders' P&Ls are often correlated as they collectively go through good and bad times, so gauging one trader's performance relative to another may be misleading if we compare their P&Ls at different times. However, as reported above, we controlled for the possibility of a missing time variable affecting P&L.

2D:4D Measurement. 2D:4D was determined from right-hand measurements only, because right-hand digit ratios have been shown previously to display more robust sex differences and are thus thought to be more sensitive to prenatal androgens (37, 38).

When measuring 2D:4D from soft tissue, care must be taken to distinguish regular from irregular or secondary creases. Irregular creases form later than regular creases, after the 11th week of gestation when the fingers start to bend, disrupting the dermal surface (25, 39). For example, fingers often develop an extra crease that is parallel, but distal, to the metacarpophalangeal crease. When this pattern is found, digit measures are taken from the proximal crease. Also common is an oblique crease angled off from the proximal crease, giving the appearance of a horizontal Y, or several oblique creases feathering the major crease (25). In these cases, measurement is taken from the middle of the Y pattern. On rare occasions, the proximal regular crease may be broken or unconnected, indicating a gap in the digital pads during development, and the broken crease may overlap in the middle of the finger. In the one case in our study where this pattern occurred, we averaged measures from the 2 halves of the broken crease. Last, it is possible, but again rare, to encounter a major crease that is indiscernible among a pattern as complicated and unique as a fingerprint (39). The only print in our study to display this pattern had already been excluded because of a broken finger. Traders' handprints were measured for 2D:4D by one of the authors (J.M.C.) and by an independent observer using callipers accurate to 0.2 mm, and these measures displayed a high repeatability (intraclass correlation = 0.974).

2D:4D research has often encountered difficulties with behavioral variables, difficulties that have led to inconsistencies between published results.

It should be noted that these inconsistencies exist largely between studies measuring psychological variables, such as aggression, status seeking, and perceived social dominance (40). Variables such as these are notoriously difficult to define and measure with any degree of repeatability. However, complications are not so common in 2D:4D research looking at performance variables that can be measured with less ambiguity. For example, achievements in sports such as soccer (12) and skiing (14), and performance in running and athletics (41) are more easily measured, and thus they display more consistent relationships with 2D:4D. The financial markets offer particularly promising variables in this respect. Financial variables, such as P&L, volatility, and years of experience, are objective and readily measured. The objective nature of our dependent variables goes some way toward accounting for the high statistical significance of the relationships we observed.

Market Volatility. To measure asset price volatility, we used the annualized standard deviation of the price changes of the Euribor futures contract. A total of 77% of the traders traded a European interest rate future, and the other traders, whose main trading security was a stock index, also traded interest rate futures as a secondary trading instrument. The estimation of a coefficient relating variance of Euribor to P&L converged for 38 of the 44 traders.

Statistics. The right-skew in the P&L data was corrected by a Box-Cox transformation. All results remained significant or displayed greater significance and effect size if we used the alternative of a cube root or rank-order transformation. 2D:4D data approximated a normal distribution (SI). When reporting correlations with a single independent variable, we used Pearson correlation coefficient; where R^2 is reported instead, we were using a robust regression to dampen the effects of outlying data. Statistical analyses were performed with Stata, release 10/SE (Stata).

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