Transferring Cognitive Talent Across Domains: The Case of Finance

Kristian Rotaru
Monash University
Petko S. Kalev
Latrobe University
Nitin Yadav
University of Melbourne
Peter Bossaerts (peter.bossaerts@unimelb.edu.au)
University of Melbourne

Research Article

Keywords: Theory of Mind, investment, cognitive talents

Posted Date: July 29th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-598488/v2

Transferring Cognitive Talent Across Domains: The Case of Finance

Kristian Rotaru[1,2], **Petko S. Kalev**[3], **Nitin Yadav**[4], **and Peter Bossaerts**[4,5,*]

[1]Monash University, Monash Business School, Caulfield East, VIC 3145, Australia
[2]Monash University, BrainPark, The Turner Institute for Brain and Mental Health, School of Psychological Sciences and Monash Biomedical Imaging Facility, Clayton, VIC 3800, Australia
[3]Latrobe University, Department of Finance, Melbourne, VIC 3086, Australia
[4]University of Melbourne, Brain, Mind and Markets Lab, Parkville, VIC 3050, Australia
[5]University of Cambridge, Faculty of Economics, Cambridge, CB3 9DD, United Kingdom
[*]peter.bossaerts@unimelb.edu.au

ABSTRACT

We consider Theory of Mind, the ability to correctly predict the intentions of others. The skill requires abstraction from one's own particular circumstances. Here, we posit that such abstraction can be transferred successfully to other, non-social contexts. We consider the disposition effect, which is a pervasive cognitive bias whereby investors, including professionals, improperly take their personal trading history into account when deciding on investments. We design an intervention policy whereby we attempt to transfer Theory of Mind skills, subconsciously, to personal investment decisions. In a within-subject repeated-intervention laboratory experiment, we record how the disposition effect is reduced by a very significant 85%, but only for those with high Theory of Mind skills. No such transfer is observed in subjects who score well only on the emotional dimension of interpersonal skills. Our findings open up a promising way to exploit cognitive talents in one domain in order to alleviate cognitive deficiencies elsewhere.

Introduction

Theory of Mind (ToM) refers to the ability to impute mental states to others that may be different from one's own[1] (Fig. 1A). To be good at it, and hence to possess good social cognitive skills, abstraction is required. One's own personal circumstances are to be abstracted from in order to better gauge the intentions of others. This is of utmost importance in many situations, such as strategic interaction[2]. But abstraction is needed not only in social situations. Here, we consider investments in the context of finance.

One of the most pervasive cognitive biases affecting investors, even professionals, is the disposition effect (DE)[3,4]. This bias emerges when an investor hangs on to losses too long while selling assets too quickly after gains. Losses and gains are defined with respect to the price at which the investor acquired the position: a loss (resp. gain) is incurred when the current market price is below (resp. above) the acquisition price. Since market prices evolve irrespective of actions from a single individual, rational investment decisions rely solely on future prospects, not on a person's historical experience. For instance, personal losses incurred in the recent past merely amount to "sunk costs," and hence are irrelevant. To avoid DE, it is therefore of primordial importance to be able to abstract away from one's own history.

Consequently, the ability to think outside personal context is common to well-pronounced ToM and to avoiding DE. As such, individuals who are talented at ToM may be able to deploy their ability to abstract to the domain of finance. Here, we ask how the transfer of this skill can be accomplished in practice. Importantly, we wanted the transfer to be subconscious, because many aspects of investments (mathematical intricacies, unusual vocabulary, unusual uncertainty) may stand in the way of conscious transfer; conversely, consciously becoming financially literate may come at the cost of overconfidence[5].

We designed a training scheme aimed at subconsciously transferring ToM skills to investments. We performed a longitudinal (multiperiod) experiment with a four-week treatment washout period to determine its efficacy[6]. Our methodological approach adopts the key premise underlying cognitive training schemes: a specific cognitive skill is exploited through a structured intervention, resulting in the intended behavioral change (e.g.[7]). To our knowledge, we are the first to propose the use of a cognitive training scheme to transfer a skill from one domain (the social sphere) to another (investments).

We administered additional tests in order to confirm that the skills transfer scheme worked because of the cognitive dimension of social skills, as opposed to the emotional dimension. Investors with better generic social skills have been shown to predict more accurately price changes in markets with insiders and to sell more timely when bubbles emerge[8–11]. In our experiment, however, participants who scored high on the cognitive social skills tests were initially no less susceptible to

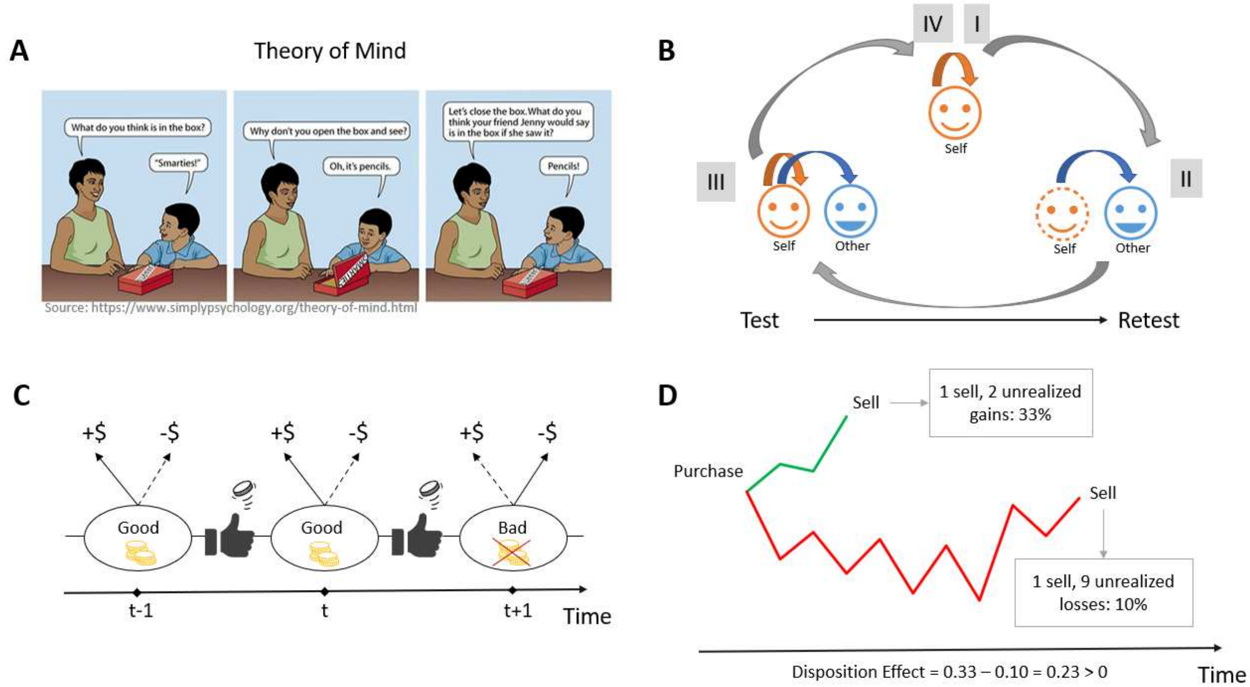

Figure 1. (A) Theory of mind is the ability to abstract from one's own experience to correctly guess the mindset of another. Here, the child incorrectly abstracts from its knowledge that the box contains pencils rather than smarties when predicting Jenny's response. Hence, the child has incorrect Theory of Mind. (B) Structure of one sitting in the experiment: (I) and (IV) Participant plays an investment game for self; (II) Participant plays the game for someone other, who never remains invested more than one round; (III) Participant makes choices for self and for other. (C) Stock price changes are more likely to be positive in the good regime; conversely, stock price changes are more likely to be negative in the bad regime; regime switches are random across rounds, determined by a biased coin flip. Under the Bayes-optimal strategy, gains rarely are realized, while losses are realized regularly. (D) Computation of the DE (Disposition Effect) metric: under the green price history between Purchase and Sale, gains were not realized for 2 rounds; under the red price history between Purchase and Sale, losses were not realized 9 rounds. The metric equals the difference between the percentage of periods with realized gains relative to all periods with gains (paper gains or realized gains) and the percentage of periods with realized losses relative to all periods with losses. In the example here, the player hangs on to losses much longer, and hence, DE is positive.

DE. We deployed eye-tracking to verify that successful skills transfer is associated with a reduction in attention paid to the acquisition price[12].

Seventy six participants were subjected to two interventions, separated by four weeks to allow for treatment washout and subsequent re-uptake[13,14]. The size of the sample was determined by means of power analysis based on[12], which demonstrated a small (25%) impact on DE from simply deleting information about the acquisition price. Each of the interventions consisted of four sessions: (I) a session organized along the lines of[15], to measure the extent to which the participant's investment decisions are affected by the DE; (II) a session whereby the participant (advisor) chooses investments for a person (advisee) selected by the advisor; importantly, the advisee always realizes gains (or losses) immediately after the end of an investment trial, so the advisee is never invested when the participant recommends investment; (III) a session that combines (I) and (II), whereby the advisor chooses investments for herself, as well as for the advisee (selected in the previous session) who immediately realizes gains (or losses) upon conclusion of an investment trial; (IV) a repetition of session (I), to measure the impact on DE of the training intervention. See Fig. 1B.

Sessions (II) and (III) constitute the core of our intervention. There, participants are asked to decide on an advisee's behalf. The best decision requires them to ignore their own situation, because the advisee is never invested at the moment the advice is given, while participants may be invested (in Session III). By requiring decisions for both the advisee and for themselves, in Session (III) we nudge the participant to reflect on the relevance for his/her own investments of the action chosen for the advisee. If s/he is holding a position and the decision for the advisee is not to invest, why would the participant him/herself remain invested? If the advice is to buy, then the participant should conclude that s/he too should remain invested. Etc.

In all sessions, the investment game was the same. Participants took positions (long; short) in one share of a security called "stock" that went through good and bad regimes. In the good regime, the stock price went up the majority of the time; in the bad regime, the stock mostly went down. Regime switches occurred randomly. See Fig. 1C. Participants knew that there were regime switches, they were also aware of probabilities, and the possible magnitudes of the outcomes in each regime. In any trial, the regime had to be inferred, as participants were never told which regime the stock was in. But a sequence of mostly positive (resp. negative) price changes revealed that the stock most likely was in the good (resp. bad) regime, and hence, that one was to be "long," which means that one should have bought (resp. "short," i.e., selling the stock with the aim of buying back later at a higher price). At the end of each of the four sessions in the test and retest parts of the study, participants' holdings of the stock A were liquidated, and the cash value of their position was recorded. Participants' incentives depended on the final value of their portfolio at the end of each session.

Before trading sessions (II) and (III) of both the test and retest treatments, participants were shown photographs of 21 clients (The photographs were selected from the Nencki Affective Picture System[16]), among which they could select one whom they would advise. In session (IV), participants only traded for themselves, as in the session (I).

We measured DE as in[17]. The measure compares the frequency with which gains are realized against the frequency of loss realizations. See Fig. 1D. DE emerges if this measure is positive: more gains than losses are realized. In fact, the Bayes-optimal policy in our investment game even implies that more losses have to be realized than gains. That is, the DE measure should be negative (-0.73). This extreme number assumes, however, that one can immediately switch from a long to a short position and *vice versa*, something we disallowed: a long position had to be liquidated before a short position could be taken in the subsequent trial. In prior experiments, participants rarely did better than reaching balance between realized gains and losses[15].

We gauged ToM skills using three subscales of the Awareness of Social Inference Test - Revised (TASIT-R[18]). The subscales delineate neurocognitive skills associated with social and emotional cognition. The subscales are: the Emotion Evaluation Test (EET), the Social Inference–Minimal (SI-M) test, and the Social Inference–Enriched (SI-E) test. EET gauges the affective dimension of social cognition, while the social inference (SI) tests measure the cognitive dimension. Different forms were used between the test (Form A) and re-test (Form B) sitting. All the tests are used in clinical settings. We refrained from using popular academic ToM tests, such as the "Eye Gaze Test"[19], because they confound the cognitive and the affective aspects of social cognition. Scores on the test were used to predict DE level in a session and changes in levels across sessions and sittings.

Eye movements, and from them, eye fixations, were recorded using a table-mounted eye tracking system (Tobii TX300; see Supplementary Information). For each trial, eye fixations were calculated in relation to the areas displaying the acquisition price and the overall trading dashboard.

To avoid deception, we referred in the instructions to the investment game as the "Disposition Game," and described it as a game where "you will attempt to maximize profits while buying and selling a security and avoiding the Disposition Effect" (See Supplementary Information, Appendix C). Participants were not incentivized monetarily to improve DE. If asked, DE was explained as the tendency to sell too early on gains while hanging on to losses too long. Participant earnings only depended on the final value of the positions they took for their own account. No other feedback was provided besides final portfolio value in a trading session. The putative role of the investment advice to others in potentially mitigating DE was not explained.

Results

Seventy six undergraduate and postgraduate students voluntarily participated in this study. Eight participants (10.53% of the original sample) were removed from the sample as they did not attend the retest laboratory sessions. The behavioral analyses were therefore based on the remaining 68 participants. Of these, 52.9% were male, 45.6% were female, while one participant (1.5% of the sample) preferred not to disclose the gender. The average age of the participants was 21.22 years (SD = 1.92), ranging from 18 to 27 years. 16.2% of the participants had prior trading experience outside the academic setting, while the rest (83.8%) did not have such experience. In the analyses of eye tracking data, further five participants had to be removed due to a high amount of missing eye tracking data (we imposed a data quality threshold of 85%; see Supplementary Information).

The average participant displayed a highly significant tendency to more frequently realize gains than losses (mean DE measure = 0.12, $p < 0.001$). After Holm-Bonferroni Familywise Error (FWE) correction, DE scores overall did not increase with scores on the six social skills tests ($p > 0.10$). When averaging scores across forms A and B of the SI-E test, participants with above-median average scores realized gains with a frequency that was 14.8% percentage points higher than the frequency for losses (SD = 0.31).

Overall, scores on tests of cognitive dimensions of SI tests, whether taken during the test or re-test sitting, predicted significant (SI-M, A Form: $p = 0.05$; SI-M, B Form: $p = 0.006$; SI-E, A Form: $p = 0.02$; SI-E, B Form: $p < 0.001$) reduction in DE from the first session in the test sitting (I) to the last session in the re-test sitting (IV) (Fig. 2A), while scores on tests of emotional social cognition (EET) did not ($p > 0.10$, both Forms) (Fig. 2A, inset). Holm-Bonferroni FWE correction[i] at $p = 0.05$ confirms the significance of the effect of social cognition on reduction in DE through the training intervention for the Form B versions of the cognitive Theory of Mind tests (taken during the re-test sitting); the Form A versions (taken at the initial

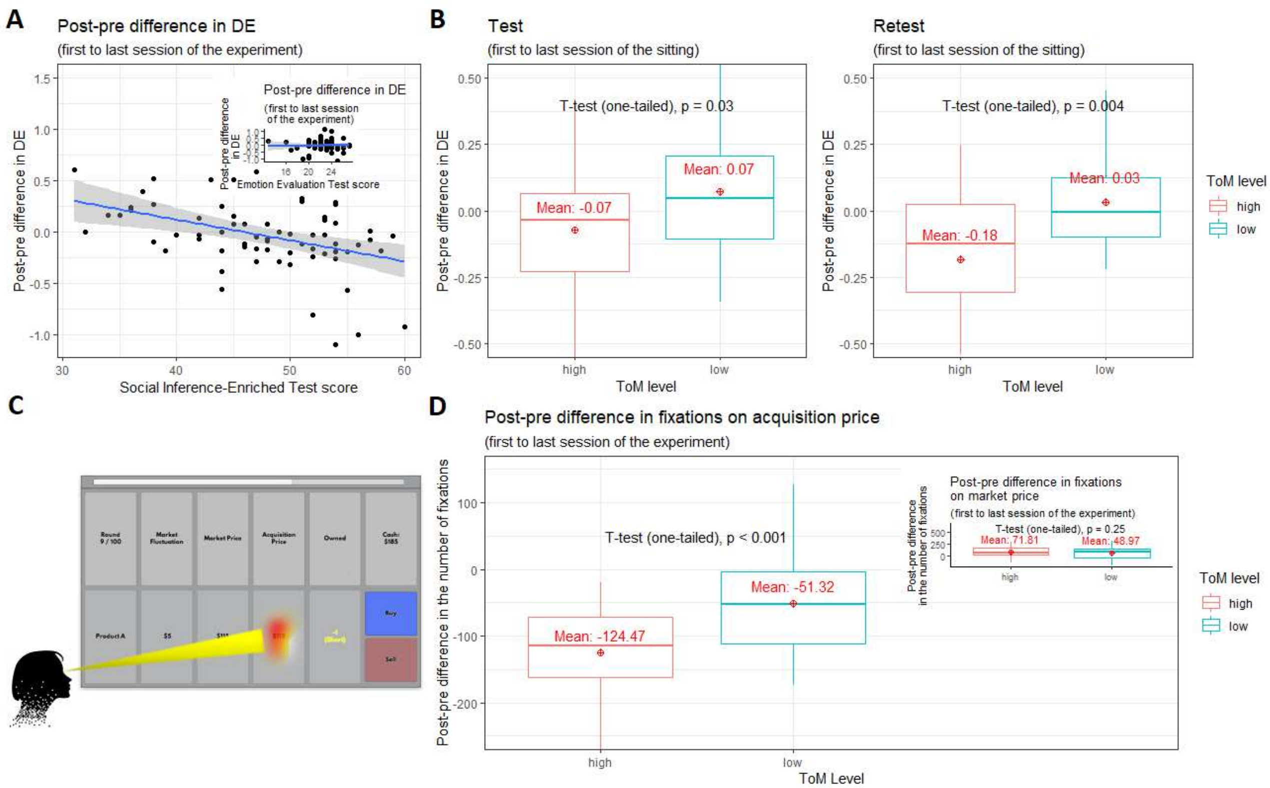

Figure 2. (A) Disposition Effect (DE) decreases significantly from session I of first sitting to session IV of second sitting, as a function of score on the Social Inference-Enriched (SI-E) test score. (Inset: For comparison, DE does not change as a function of the Emotion Evaluation Test (EET) score). (B) Boxplots of changes in DE for two cohorts based on median split of average SI scores, during test sitting (Left) and retest sitting (Right). (C) Display of game interface, featuring Round, Market Fluctuation since previous round, Market Price in current round, Acquisition Price, indication whether stock is Owned (+1) or sold short (-1), Cash still available in round, and two choice panels (Buy or Sell; if position is long (+1), Buy is unavailable and hence grayed out; if position is short (-1), Sell is unavailable and hence grayed out). Here, participant's eye fixation is on Acquisition Price panel. (D) Boxplots of changes in number of fixations on acquisition price panel, from session (I) in first sitting to session (IV) in second sitting. (Inset: For comparison, change in fixations on market price panel.)

test sitting) are insignificant, but only marginally so. One point increase in the scores produced a reduction in DE of between 1 and 2 percentage points (depending on the test and the form used).

Averaging SI-E scores across forms A and B of an individual and performing a median split across participants[20] produced a large improvement (drop) in the mean DE scores, of 85.4%, in the group above the median. A paired-sample t test (one-tailed) indicated a significance of $p = 0.04$. In contrast, the group below the median actually increased its mean DE score (from 0.09 to 0.14), though this increase was not significant ($p > 0.10$). Within-sitting effects on DE scores are displayed in Fig. 2B.

There was marginal evidence (FWE $p < 0.10$) of cognitive social skill-dependent resurgence of DE between the last session (IV) in the test sitting and the first session (I) in the retest sitting, but ultimately the strong and highly significant training effect for high scores on social cognition in the re-test sitting more than offset this reduction. Even without correction for multiple hypothesis testing, scores on tests of affective social skills (EET tests) never produced significant ($p > 0.05$) impact on DE through training (see Supplementary Information for details). A comprehensive analysis of levels and changes of DE across all stages of the training is provided in the SI.

We then investigated whether successful trainees stopped paying attention to the cue that was key to DE, namely, the price at which they acquired a position. Without attending to this price, gains and losses were undefined, and DE could have emerged only by accident (it could of course have been the case that participants always remembered the acquisition price, but this should be considered implausible given the amount of data that the participant would have had to retain). We measured selective aspects of participants' attention using eye gaze[21,22]: if participant's eyes were oriented towards an object (e.g., the purchase price), we assumed that she was paying more attention to the object than to others on the screen. Following[23], total fixation count on the trading dashboard was used as the base measure of eye gaze fixations, and fixations on an area of interest (AOI) was counted against this base. As area of interest, we took the cell in the trading window displaying the acquisition price (see Fig. 2C). Fig. 2D shows boxplots of the average number of fixations on the acquisition price relative to total number of fixations during the last session (IV) of the retest sitting (i.e. post-pre difference in total number of fixations on acquisition price), stratified by cognitive social skill score (average of SI scores per individual, median split across individuals). A two-sample t test of the differences in the means across groups produced a highly significant p value ($p < 0.001$, one-tailed). In way of contrast, change in fixations on the current market price relative to total number of fixations did not differ significantly ($p > 0.10$) across ToM groups (Fig. 2D, inset). The current market price is a relevant piece of information regardless of whether one's choices display DE.

Discussion

We proposed and tested a novel cognitive training scheme meant to transfer the human capacity to abstract from one's own history to avoiding an investment bias which has its roots in false reference to personal history. Our longitudinal test-retest experiment demonstrated an increase in efficacy of the scheme as a function of the score on tests for cognitive social skill. Scores on tests for affective skill in social interaction did not correlate with efficiency changes.

Participants who scored above the median on our cognitive social skill tests reduced their average DE from about 15% to about 2%, a reduction of more than 85%. The above-median participants thus ended up, on average, balancing the frequency with which gains and losses were realized. A significant fraction managed even to realize more losses than gains, consistent with the Bayes-optimal policy: [1st quartile, -0.04]. Participants below the median scored worse on DE after training (DE scores doubled, from 0.08 to 0.14 on average) but this difference was insignificant ($p > 0.10$). Consistent with the putative role of ToM we found that our training scheme produces significantly higher DE improvements the higher one scores on the cognitive skills tests, but not the emotional inference tests.

Our intervention builds on the role that social cognition plays as a higher-order cognitive skill. We disregard interaction between DE and social environment. Such interaction has been documented: the desire to manage self-image, for instance, may exacerbate DE when one's actions are being scrutinized by others[24]. We would argue that our training scheme is even more relevant in such circumstances, since it requires one not only to abstract from personal investment history, but also to abstract from being tracked by others.

Our experiment does not necessarily shed any light on the causes of the DE, only that it can be attenuated by transfer of ToM skills, and that this attenuation increases with ToM skill. Other known, albeit controversial, ways to reduce DE are financial education[25,26] and investment experience[27,28]. The literature has also considered the role of contextual cues. For example, using a between-subject laboratory experiment,[12] tests whether reducing the saliency of a stock's purchase price by not displaying it on the trading dashboard would result in a reduction of the disposition effect. They recorded a drop of 25% in DE, compared to our 85%. Likewise, a natural experiment involving salience of the purchase price increases DE by 17%[29]. There are doubts, however, that manipulating display of acquisition prices would work in practice: traders and investors may expect to see acquisition prices; deletion thereof may draw attention, and hence produce the opposite effect from intended.

Our ToM skills transfer training should work in other contexts as well. Most closely related is the *sunk cost fallacy*[30], whereby managers, politicians and administrators stick to an investment (e.g., an inner-city metro transit system construction) even if nobody would want to take it over for a positive price, merely because they have already spent resources on it in the past. More generally, ToM skills should be able to help overcome the ubiquitous use of faulty (and often manipulable!) reference points in decision-making[31] when these reference points relate to one's personal circumstance.

There is a close relationship between Bayesian inference and Theory of Mind (ToM). Both concern the determination of hidden (latent) variables: intentions of others for ToM; causes behind observables in the case of Bayesian inference. It is therefore not surprising that search for the neurobiological foundations of *either* of them produced results that are relevant for *both*. Regions such as paracingulate cortex or temporo-parietal junction appear to be engaged in both tasks[32] and attempts to distinguish their involvement have rarely been met with success[33]. It could be that search for differentiation is futile, for indeed, besides context, is there any difference between discerning, through actions, intentions of an opponent in a strategic game[2], and discerning, in a probabilistic task, through accumulated rewards, whether contingencies have reversed[34]? The present study underscores how close the two are, in showing that talent in one context can become skill in another one.

The latter raises an important question: can we accomplish the opposite transfer? Especially in the context of certain types of autism, can one convert, through training of the kind advocated here, successful investment skill into improved social cognition? If so, novel therapies for people with intellectual disabilities could be envisaged.We leave this for future research.

Methods

We ran a longitudinal pre-post intervention design[6]. Ethics approval was obtained from Monash University, where the research study was conducted; Ethics Number CF16/346 - 2016000160. All methods were carried out in accordance with relevant guidelines and regulations. Informed consent was obtained from all participants prior to the experiment. All participants were at least 18 years old. See Supplementary Information for details.

To test for potential washout of the treatment effect, the experimental treatments were administered twice (test and retest sittings) within an interval of four weeks. The disposition effect (DE) was measured at the beginning and end of each sitting.

In the statistical analysis of the results, we chose the first set of dependent variables (DVs) to be based on an individual measure of the disposition effect, as operationalized in[17] and utilized among others by[12,15,35,36]. This measure was calculated as the difference between the Proportion of Gains Realized (PGR) and Proportion of Losses Realized (PLR). PGR (PLR) was calculated as a ratio between the number of realized gains (losses) and the sum of the number of realized gains (losses) plus the number of paper gains (losses). *Paper* gains/losses occurred when a participant decided not to divest.

The second set of DVs was based on the difference between individual disposition effect scores obtained for each of the trading sessions. They were meant to provide a measure of learning and improvement. The third set of DVs was associated with the degree of a participant's attention to the acquisition price compared to overall attention paid to the trading dashboard. These measures captured the proportion of eye fixations on the acquisition price relative to eye fixations on the overall dashboard.

Independent variables (IVs) were based on ToM, as assessed using three subscales of the Awareness of Social Inference Test - Revised (TASIT-R[18]), which delineated and measured individual neurocognitive skills associated with social and emotional cognition. See main text for subscales. With these IVs, we investigated whether the level of social cognition (as per the social inference subscales of the TASIT-R tests) versus the level of emotional cognition (as per the emotional inference subscale of the TASIT-R tests) were associated with (i) the level of the DE measure, and (ii) the reduction of DE during the experimental interventions.

The experimental task closely followed that of[15], which was based on the stock trading task introduced by[37]. Participants were given the opportunity to trade one stock, named stock A. Each participant was allowed to hold a maximum of one ('1') share and a minimum of minus one ('-1') shares (negative positions corresponded to short-selling). Participants bought or sold at the current-trial market price.

The price path of stock A was governed by a two-state Markov chain with a good state and a bad state. Suppose that, in trial t, $t = 1, 2, ..., 100$, there was a price update for stock A. If stock A was in the good state at that time, its price increased with probability 0.55 and decreased with probability 0.45. Conversely, if it was in the bad state at that time, its price increased with probability 0.45 and decreased with probability 0.55. The magnitude of the price change was drawn uniformly from $\{5, 10, 15\}$, independently of the direction of the price change. The state of each stock evolved over time in the following way. Before trial 1, stock A is randomly assigned a state. With the price update in trial $t > 1$, the state of stock A in the trial remained the same as in trial $t - 1$ with probability 0.8, but switched with probability 0.2.

The computer graphical user interface was written in Unity3D (http://unity.com). It gave participants access to their holdings, current price in the trial, acquisition price (if invested), and market fluctuation (price change since last trial). When trading on behalf of another, the graphical user interface was identical, except that the acquisition price did not apply (since the advisee never cashes in every round), and a picture of the (chosen) advisee was added.

Participants were paid a sign-up reward plus their earnings from trading for their personal account. In the second trading session of both the test and retest sittings, participants were asked to recommend purchases or (short-) sales to a client. Details of the client selection protocol can be found in the Supplementary Information. After selecting a client (an advisee), participants traded on behalf of their advisee. Importantly, the advisee never held on to investments for more than one trial. That is, gains and losses were realized immediately. As a result, there could not be a DE.

During game play, eye movements were recorded using a table-mounted eye tracking system (Tobii TX300; Tobii, Stockholm, Sweden) with a temporal resolution of 300 Hertz and a screen resolution of 1920 x 1080 pixels. Eye fixations were computed using the velocity-based I-VT algorithm[38].

More information, including instructions, can be found in the online Supplementary Information.

Notes

i. In total, we ran 6 tests (one for each social skill test). Significance was determined as follows: order p values from small ($k = 1$) to large ($k = 6$); the kth test value is deemed to be significant at the level α if $p(k) \leq \alpha/(m+1-k)$ where m is the number of hypotheses to be tested; here: $m = 6$. If $\alpha = 0.05$ then the smallest p should be ≈ 0.008 for the corresponding test (i.e., the test with smallest p value) to reject. For the next test to reject, its p value should be at most 0.01. Etc.

References

1. Premack, D. & Woodruff, G. Does the chimpanzee have a theory of mind? *Behav. Brain Sci.* **1**, 515–526 (1978).

2. Hampton, A. N., Bossaerts, P. & O'Doherty, J. P. Neural correlates of mentalizing-related computations during strategic interactions in humans. *Proc. Natl. Acad. Sci.* **105**, 6741–6746 (2008).

3. Shefrin, H. & Statman, M. The disposition to sell winners too early and ride losers too long: Theory and evidence. *J. Finance* **40**, 777–790 (1985).

4. Coval, J. D. & Shumway, T. Do behavioral biases affect prices? *J. Finance* **60**, 1–34 (2005).

5. Tokar Asaad, C. Financial literacy and financial behavior: Assessing knowledge and confidence. *Financial Serv. Rev.* **24** (2015).

6. Harris, A. D. *et al.* The use and interpretation of quasi-experimental studies in medical informatics. *J. Am. Med. Informatics Assoc.* **13**, 16–23 (2006).

7. Chambers, R., Lo, B. C. Y. & Allen, N. B. The impact of intensive mindfulness training on attentional control, cognitive style, and affect. *Cogn. Ther. Res.* **32**, 303–322 (2008).

8. Bruguier, A. J., Quartz, S. R. & Bossaerts, P. Exploring the nature of "trader intuition". *The J. Finance* **65**, 1703–1723, DOI: 10.1111/j.1540-6261.2010.01591.x (2010).

9. De Martino, B., O'Doherty, J. P., Ray, D., Bossaerts, P. & Camerer, C. In the mind of the market: theory of mind biases value computation during financial bubbles. *Neuron* **79**, 1222–1231 (2013).

10. Corgnet, B., Desantis, M. & Porter, D. What makes a good trader? on the role of intuition and reflection on trader performance. *The J. Finance* **73**, 1113–1137 (2018).

11. Bossaerts, P., Suzuki, S. & O'Doherty, J. P. Perception of intentionality in investor attitudes towards financial risks. *J. Behav. Exp. Finance* **23**, 189–197 (2019).

12. Frydman, C. & Rangel, A. Debiasing the disposition effect by reducing the saliency of information about a stock's purchase price. *J. Econ. Behav. & Organ.* **107**, 541–552 (2014).

13. Bryck, R. L. & Fisher, P. A. Training the brain: practical applications of neural plasticity from the intersection of cognitive neuroscience, developmental psychology, and prevention science. *Am. Psychol.* **67**, 87 (2012).

14. Ngandu, T. *et al.* A 2 year multidomain intervention of diet, exercise, cognitive training, and vascular risk monitoring versus control to prevent cognitive decline in at-risk elderly people (finger): a randomised controlled trial. *The Lancet* **385**, 2255–2263 (2015).

15. Frydman, C., Barberis, N., Camerer, C., Bossaerts, P. & Rangel, A. Using neural data to test a theory of investor behavior: An application to realization utility. *The J. Finance* **69**, 907–946 (2014).

16. Marchewka, A., Żurawski, Ł., Jednoróg, K. & Grabowska, A. The nencki affective picture system (naps): Introduction to a novel, standardized, wide-range, high-quality, realistic picture database. *Behav. Res. Methods* **46**, 596–610 (2014).

17. Odean, T. Are investors reluctant to realize their losses? *The J. Finance* **53**, 1775–1798 (1998).

18. McDonald, S., Flanagan, S. & Rollins, J. The awareness of social inference test (revised) (2011).

19. Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y. & Plumb, I. The "reading the mind in the eyes" test revised version: A study with normal adults, and adults with asperger syndrome or high-functioning autism. *J. Child Psychol. Psychiatry* **42**, 241–251 (2001).

20. Iacobucci, D., Posavac, S. S., Kardes, F. R., Schneider, M. J. & Popovich, D. L. The median split: Robust, refined, and revived. *J. Consumer Psychol.* **25**, 690–704 (2015).

21. Rehder, B. & Hoffman, A. B. Thirty-something categorization results explained: selective attention, eyetracking, and models of category learning. *J. Exp. Psychol. Learn. Mem. Cogn.* **31**, 811 (2005).

22. Smith, S. M. & Krajbich, I. Gaze amplifies value in decision making. *Psychol. Sci.* **30**, 116–128 (2019).

23. Holmqvist, K. *et al. Eye tracking: A comprehensive guide to methods and measures* (OUP Oxford, 2011).

24. Heimer, R. Z. Peer pressure: Social interaction and the disposition effect. *The Rev. Financial Stud.* **29**, 3177–3209 (2016).

25. Feng, L. & Seasholes, M. S. Do investor sophistication and trading experience eliminate behavioral biases in financial markets? *Rev. Finance* **9**, 305–351 (2005).

26. Dhar, R. & Zhu, N. Up close and personal: Investor sophistication and the disposition effect. *Manag. Sci.* **52**, 726–740 (2006).

27. Chen, G., Kim, K. A., Nofsinger, J. R. & Rui, O. M. Trading performance, disposition effect, overconfidence, representativeness bias, and experience of emerging market investors. *J. Behav. Decis. Mak.* **20**, 425–451 (2007).

28. Da Costa Jr, N., Goulart, M., Cupertino, C., Macedo Jr, J. & Da Silva, S. The disposition effect and investor experience. *J. Bank. Finance* **37**, 1669–1675 (2013).

29. Frydman, C. & Wang, B. The impact of salience on investor behavior: Evidence from a natural experiment. *The J. Finance* **75**, 229–276 (2020).

30. Strough, J., Schlosnagle, L., Karns, T., Lemaster, P. & Pichayayothin, N. No time to waste: Restricting life-span temporal horizons decreases the sunk-cost fallacy. *J. Behav. Decis. Mak.* **27**, 78–94 (2014).

31. Barberis, N. C. Thirty years of prospect theory in economics: A review and assessment. *J. Econ. Perspectives* **27**, 173–96 (2013).

32. Charpentier, C. J. & O'Doherty, J. P. The application of computational models to social neuroscience: promises and pitfalls. *Soc. Neurosci.* **13**, 637–647 (2018).

33. Hill, C. A. *et al.* A causal account of the brain network computations underlying strategic social behavior. *Nat. Neurosci.* **20**, 1142 (2017).

34. Hampton, A. N., Bossaerts, P. & O'doherty, J. P. The role of the ventromedial prefrontal cortex in abstract state-based inference during decision making in humans. *J. Neurosci.* **26**, 8360–8367 (2006).

35. Goulart, M., da Costa, N. C., Andrade, E. B. & Santos, A. Hedging against embarrassment. *J. Econ. Behav. Organ.* **116**, 310–318, DOI: https://doi.org/10.1016/j.jebo.2015.04.014 (2015).

36. Fischbacher, U., Hoffmann, G. & Schudy, S. The causal effect of stop-loss and take-gain orders on the disposition effect. *The Rev. Financial Stud.* **30**, 2110–2129, DOI: 10.1093/rfs/hhx016 (2017). https://academic.oup.com/rfs/article-pdf/30/6/2110/25335244/hhx016.pdf.

37. Weber, M. & Camerer, C. F. The disposition effect in securities trading: An experimental analysis. *J. Econ. Behav. & Organ.* **33**, 167–184 (1998).

38. Komogortsev, O. V., Gobert, D. V., Jayarathna, S., Gowda, S. M. *et al.* Standardization of automated analyses of oculomotor fixation and saccadic behaviors. *IEEE Transactions on Biomed. Eng.* **57**, 2635–2645 (2010).

Acknowledgements:

The authors wish to thank Arno Riedl, Guillaume Frechette, Elise Payzan-LeNestour, Jake Rose, participants at the 2018 Behavioural Insights (BX2018) Conference, and in particular Cass Sunstein, participants at the 9th Miami Behavioral Finance conference, and in particular the discussant Francesco D'Acunto, participants at the 8th Behavioural Finance and Capital Markets conference (Best Paper Award), and in particular the discussants Barry Oliver and Simon Russell, participants at the 2018 SEF Experimental Finance Conference, and 2018 SEF regional Asia-Pacific Meeting for their comments. The authors also thank the Monash Business School and the Australian Research Council (ARC LIEF grant LE130100112) for funds associated with the Monash Business Behavioural Laboratory equipment used in this study, the Commonwealth Bank of Australia for sponsoring the Rising Star Award for Financial Wellbeing presented to Kristian Rotaru for this research project at BX2018, and the University of Melbourne for funding through the R@MAP Chair of Peter Bossaerts.

Contributions:

KR and PB designed the experiment, NY provided computational support for the experiment, KR ran the experiment, KR and PB analyzed the results, all authors contributed to writing the article.

Competing interests:

The authors declare no conflict of interest.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SIfinal30Apr2021.pdf