Rise of the androids: Individual differences and similarities in HFT codes and strategies

Abstract

Research has emphasised the mechanical nature of high frequency trading (HFT) and the differences between it and human trading. This study explores the possibility that HFT mirrors individual differences between HFT practitioners (code writers and strategists). It draws on the mirroring hypothesis, according to which organisational characteristics are reflected in product designs, and on personality expression research, according to which people provide cues about their personality. Through content analysis of a series of 30 interviews with HFT practitioners, it shows that HFT code writers and strategists exhibit a wide range of HFT-related individual differences, including differences in code writing, error and exception handling, and strategy preferences. Furthermore, this study reveals that certain organisational practices (e.g. peer-reviews) limit the extent to which individual differences between practitioners can be expressed. However, it shows that, despite these organisational practices, individual differences between practitioners are reflected in HFT codes and strategies. These results suggest that HFT codes and strategies are endowed with some of the characteristics of the practitioners who wrote them. They reveal that trading behaviours, which have been attributed to human beings, propagate to algorithmic trading. Thus, this study extends behavioural finance theories to algorithmic trading. Applications for financial modelling are discussed.
Introduction

High frequency trading (HFT) – the use of state-of-the-art computers to trade on stock exchanges thousands of times a day - has become a major part of the financial markets. It has been estimated to account for 40% - 70% of trading volume in central markets, including the US equities and foreign exchange markets (Reuters Newswire, 2013). Accordingly, it has attracted considerable research attention (Brogaard, Hendershott and Riordan, 2014; Brogaard et al., 2018; Kozhan and Tham, 2012; Menkveld and Yueshen, 2018). However, HFT research has focused on the differences between HFT and human trading. For instance, it has compared between the efficiency of HFT and human trades (Foucault, Hombert and Roşu, 2016; Hoffmann, 2014). Demonstrating that HFT transactions are more similar to each other than human transactions are (Benos, et al., 2017; Chaboud et al., 2014), it has emphasised the homogeneous, mechanical nature of HFT.

The aim of this study is to enhance the understanding of the nature of HFT. In line with HFT research (Benos, et al., 2017; Chaboud et al., 2014), this study explores the reasons for the similarities between HFT trades. However, arguing that HFT computer programmes (codes) and strategies are written by people working in organisations, it examines also the ways in which the individual differences between HFT practitioners and HFT firm procedures are mirrored through it. Hence, this study explores the human aspects of HFT. It draws on theories relating organisational characteristics to product properties (Cabigiosu and Camuffo, 2012; Constantinides, Henfridsson and Parker, 2018) and theories relating people’s personality to characteristics of their creations (Hirschmüller et al., 2013; Küfner et al., 2010).

Analysing a series of interviews with HFT practitioners, this study reveals that: (1) HFT practitioners exhibit individual differences, which are related to their performance in HFT-related tasks. These individual differences include characteristics which have been traditionally attributed to other human market participants e.g. risk aversion and experience (Constantinides et al., 2011; Richards et al., 2017). However, they include also HFT-specific characteristics, such as HFT code error-handling...
skills; (2) A proportion of HFT firms employ practices, which limit the expression of individual differences between HFT practitioners in their codes and strategies; (3) Nevertheless, HFT codes and strategies mirror individual differences between the practitioners who have written them.

This study makes three main theoretical contribution to the literature on the nature of HFT. First, this study suggests that HFT is subject to human decision making biases. In HFT, each trading decision is made by computers. Therefore, HFT research has tended to neglect the human aspects of HFT and to focus on its mechanical attributes. For instance, a classical study has used risk-neutral agents to model HFT (Kozhan and Tham, 2012, p. 2133). This disregard for human characteristics can be anecdotally inferred also from the metaphor “rise of the machines”, which has been used to describe HFT (Chaboud et al., 2014; Manahov, 2018). By highlighting that, up to errors and intentional compromises, computer decisions are determined by human beings, this study portrays HFT as a form of trading, which preserves some of the traits of the people who wrote it.

Second, this study provides the literature on the similarities between HFT transactions with insights about the reasons for these similarities. Interest in the relatedness between HFT transactions has emerged because trading similarities often have a destabilising effect on the market (Benos et al., 2017; White, 2014). HFT studies have conjectured that HFT transactions are more correlated than human transactions because HFT firms use the same information and strategies (Benos, et al., 2017; Chaboud et al., 2014). This study suggests that certain organisational and individual practices limit the extent to which HFT practitioners express their individual personality through their codes and strategies. Specifically, a proportion of HFT firms encourage code similarities by setting peer-reviews, code controls, and testing procedures. In addition, HFT practitioners tend to learn or be inspired by each other. Thus, in a proportion of HFT firms, HFT transactions reflect team efforts rather than individuals’ preferences.

Finally, this study complements research on HFT similarities by exploring the way individual differences between HFT practitioners are reflected through HFT codes and strategies. It identifies a
A wide range of individual differences between practitioners, which are reflected through HFT. These differences include code writers’ education, experience, intelligence, sophistication, methodology, perfectionism, ability to write codes which run fast, error handling and precision approach. HFT reflects also strategists’ assumptions and beliefs about the market and risk preferences. Therefore, this study concludes that HFT mirrors individual differences between HFT practitioners.

**Theoretical background and research questions**

Three research streams have led to the research questions that this paper answers: individual differences in financial behaviour, personality expression research, and organisational mirroring research. This section reviews central results in each of these fields.

**Individual differences in financial behaviour**

Research has not explored individual differences between HFT practitioners. However, in contexts other than HFT, a large body of research has demonstrated that certain individual differences affect financial behaviour. In particular, risk aversion (Bonaparte, Korniotis and Kumar, 2014), education and experience (Bradbury, Hens and Zeisberger, 2015) have been repeatedly shown to influence financial decision making. For instance, risk aversion of institutional investors has been related to investors’ portfolio choices and strength of the disposition effect (Bodnaruk and Simonov, 2016). People have been shown to exhibit a wide range of attitudes towards risk (Ahern, Duchin and Shumway, 2014). Models have demonstrated that risk affects auction behaviour (Platt, Price and Tappen, 2013). Risk aversion has been related to the beliefs that market participants hold about the market (Berrada, Detemple and Rindisbacher, 2018; Kupiec and Sharpe, 1991). Beliefs about the market have been shown to affect stock price behaviour (Friesen, Zhang and Zorn, 2012).

As with risk aversion, in contexts other than HFT, education and experience have been found to affect financial decision making and performance. For example, studies have shown that fund manager education influences hedge fund performance (Li, Zhang and Zhao, 2011) and that
experience affect investment choices (Chernenko, Hanson and Sunderam, 2016). It has been established that lower education levels are positively related to under-diversification (Anderson, 2013). Directors’ acquisition experience has been demonstrated to influence firm decisions (Field and Mkrtchyan, 2017).

As research has established that certain individual differences between practitioners in financial industries other than HFT have a profound effect on their performance, I expected these individual differences to affect the performance of HFT practitioners, too. However, as HFT differs from traditional forms of trading in its level of innovation and use of technology, I conjectured that there may be additional practitioner characteristics, which affect HFT performance. Therefore, the first research question that this study asks is:

Research question 1. Which HFT-related individual characteristics differentiate between HFT practitioners?

Organisational mirroring research

The mirroring hypothesis suggests that firm characteristics are mirrored in firm products. The mirroring hypothesis has been, originally, limited to the principle that “organisations which design systems (in the broad sense used here) are constrained to produce designs which are copies of the communication structures of these organisations” (Conway, 1968, p. 31). However, it has been extended to other organisational characteristics and processes. It is now widely believed that organisational properties, such as firm structure and practices, are reflected firm products (Cabigiosu and Camuffo, 2012; Constantinides, Henfridsson and Parker, 2018).

Research has not examined the mirroring hypothesis in HFT firms. However, given that studies have established that firm products reflect the organisational characteristics of a wide range of firms, I conjectured that a similar phenomenon may occur in HFT, too. Therefore, the second research question that this study asks is:
Research question 2. Which organisational practices increase the similarity between HFT transactions?

**Personality expression research**

Extensive research has established that people are motivated to provide cues about their personality (Swann, 1983) and that they do so both deliberately and automatically (Hirschmüller et al., 2013). Indeed, people are able to identify author personality by reading their stories (Küfner et al., 2010). Personality can be even inferred accurately through social media messages, whose length is limited to 140 characters (Orehek and Human, 2017; Qiu et al., 2012). Therefore, people’s creations encapsulate aspects of their personalities.

In line with research about the effect of personality on job performance (Barrick and Mount, 1991), the performance of code writers has been found to be related to their personalities. Specifically, code writer’s personality has been related to software quality (Acuña, Gómez and Juristo, 2009), team performance (Yilmaz et al., 2017), and software task choices (Capretz, Varona and Raza, 2015).

Research has not examined the expression of the personality of HFT practitioners on HFT codes and strategies. However, as studies have shown that people’s creations reflect their personalities and that code writers’ personalities affect their performance, I expected that the personalities of HFT practitioners would be reflected through the codes and strategies that they produce, too. Therefore, the third research question, that this study asks is:

Research question 3: How are individual differences between HFT practitioners reflected in HFT codes and strategies?
Method

HFT studies have predominantly employed objective, quantitative methods. The use of objective, quantitative methods has provided a wealth of important results about HFT (Benos, et al., 2017; Chaboud et al., 2014). However, the mystery surrounding the HFT industry, its secrecy, practitioners’ non-disclosure agreements and HFT firm rules (Cooper, Davis and Van Vliet, 2016), do not enable direct access to HFT codes. Therefore, objective methods are not suitable for the study of HFT codes and strategies.

However, recently, it has been acknowledged that qualitative research methods, and especially in-depth interviews, could provide rich insights about HFT (Mackenzie, 2018). Interviews have been employed also in studies about other financial industries (e.g. Almandoz, 2012). Furthermore, a study has found that subjective reports provide accurate measures of firm performance (Wall et al. 2004). Therefore, this study explores the research questions using interviews. Different parts of the same interviews have been analysed in a different study (Author, 2019).

Participants

Thirty people acted as participants in the study (29 men and one woman; age average 38.53 years, std: 7.46 years, min: 25 years, max: 51 years). Participant group included HFT code writers (computer programmers), quantitative strategists, quantitative analysts, algorithm developers, traders, consultants, ultra low latency data scientists, and managers of HFT companies (a CEO, a director and a vice president). Twenty-two of the participants worked in UK. Eight participants worked in the US, Australia, Hong Kong, or China (Author, 2019).

Participants were approached through LinkedIn (https://www.linkedin.com/) using the key words: ‘High Frequency and C++’, ‘High Frequency Trader’, ‘Low Latency and C++’, or ‘Low Latency Trader’. C++ was chosen as a key word for the search because many HFT practitioners use C++.
Participant number was chosen using the data saturation criterion (Guest, Bunce and Johnson, 2006). After the 25th interview, participants did not add new themes to the results. Furthermore, a study has concluded that having 30 participants is suitable for interview studies (Saunders and Townsend, 2016).

To maintain participants’ anonymity, I randomly chose for each participant a 2-letter identifier. I refer to each participant using their identifiers. In addition, I removed any detail that could disclose participants’ identity from the transcriptions of the interviews. Table A in the appendix presents participants’ identifiers and positions (Author, 2019).

**Procedure**

I interviewed 28 participants individually in face to face meetings, Skype video meetings (https://www.skype.com/en/), or over the phone. Two participants preferred to fill in a questionnaire. All interviews were recorded, except for three interviews (due to participants’ requests). The average length of the interviews was 72.63 minutes (std: 29.00 minutes, min: 26.3 minutes, max: 132 minutes). Table A in the appendix presents the data collection procedures (Author, 2019).

In line with a study about the HFT industry (Mackenzie, 2018), I used semi-structured interviews. In semi-structured (informal) interviews, the interviewers pre-define topics or questions for discussions. However, they can personalise the specific questions to each participant during the interview. Semi-structured interviews are considered more natural and pleasant for the participants than other forms of interviews (Coolican, 1995).

Participants were asked whether their code or trading strategies reflected their personality. Depending on the nature of the conversation, participants were asked also what differentiated between the code or strategies which they wrote. They were asked additional questions according to their answers. (In other parts of the interviews, participants’ work experience and ethical
considerations were examined. Results, referring to these parts of the interviews are reported in Author, 2019). I offered each participant the option to obtain the results of the study.

**Data Analysis**

I transcribed participants’ answers. Then, I conducted content analysis of the transcriptions. I started by formulating codes. Codes reflect the ideas or notions, that participants express. Then I grouped codes into themes, and themes into dimensions (Corbin and Strauss, 2008; Gioia, Corley and Hamilton, 2013). I analysed the data using Atlas.ti, a content analysis software.

**Findings**

Content analysis has yielded three main dimensions: ‘HFT practitioners exhibit individual differences which are related to their performance’, ‘Organisational and individual practices affect HFT similarities’ and ‘HFT reflects individual differences between HFT practitioners’. Below, I describe the concepts and themes, that have led to the formulation of each dimension.

**HFT practitioners exhibit individual differences, which are related to their performance**

The dimension ‘HFT practitioners exhibit individual differences which are related to their performance’ has emerged through the analysis from three themes: ‘HFT practitioners exhibit individual differences in code writing’, ‘HFT practitioners exhibit individual differences in error and exception handling’, and ‘HFT practitioners exhibit individual differences in strategy preferences’. All the quotations referred to in this section are presented in Table 1.

**HFT practitioners exhibit individual differences in code writing.** In the interviews, participants have referred to a wide range of individual differences in code writing, including code writers’ age, education, experience, cognitive abilities, skills (quotations Q1.1-Q1.5), coding preferences, style and
clarity (quotation Q1.6-Q1.8). Age, education, experience, cognitive abilities and skills have been shown to have a central effect on financial decisions and outcomes in non-HFT contexts (Anderson, 2013; Chernenko, Hanson and Sunderam, 2016; Field and Mkrtchyan, 2017; Li, Zhang and Zhao, 2011). However, this study emphasises their importance in the context of HFT. For instance, SK (a senior software engineer) expressed the idea that individual differences in experience affect code writing as follows:

SK: “It all depends on what you have experienced yourself, like, even between two seniors, you might say, well, I handle things one way, because I was once in this situation, and the best way to handle it was this, but I didn’t do it and I was always sorry I didn’t […] And the other person has the opposite experience, even they are at the expert level, people who design the language, they have arguments over what is the best way to do things. And there often isn’t one right answer. So […] it depends on individual experiences. On what you learnt is the right way to do things, on how you like to do things.”

Individual differences in coding preferences, style and clarity have not been studied. Participants in this study have identified many individual differences in coding preferences, including the way coding languages are used (e.g. the use of functions and structures), the degree of automation of the code (the extent to which human beings interfere with its running) and code optimisation. Participants referred also to a wide variety of styles, determined by the visual aspects of the code (e.g. variable and function names), its elegance (e.g. the extent to which the code is concise) and comment style. Individual differences in the extent to which HFT code is readable and adaptable have been observed, too. For example, VR (an HFT trader and programmer) has exemplified individual differences in optimisation preferences as follows:

VR: “Good people don’t only care about what they are writing, right […] [Some people] just want things to work, some coders just want something that works, right, and they are just writing code at, you know, a very fast pace and they are like, you know, “let it run, oh it works,
ok, fine, I am not touching that anymore.” And that’s very convenient to do that. I would like to do that, because, it’s, you know, it is easy to tick, right, “I have done it, it runs fine”. But […] even if it runs right, I will try to go back into it and see whether I could optimise it and make it better, either more understandable or more reliable.”

**HFT practitioners exhibit individual differences in error and exception handling.** In HFT, coding errors may cause severe financial losses and increase trading risk (Menkveld and Yueshen, 2018). Therefore, many participants considered error handling (preparing the code for unusual situations, debugging, and testing the code) a central task. However, they identified individual differences in the way errors are handled (quotation Q1.9), as well as coders’ debugging skills (quotation Q1.10), failure likelihood assessment (quotation Q1.11), defensive coding (quotations Q1.12 and Q1.13), and the extent they rely on the defensiveness of code written by others (quotation Q1.14). For instance, BH (a senior software developer) has stated that there are individual differences in code errors:

BH: “My personality has influence on the code, from the perspective, that I have a very high commitment on correctness and stability. So, when I write code, the code must be correct. I apply a lot of techniques in order to make sure that the code is correct. OK? So, this is my personality. Some people, they are not like that […] So, OK, there is this perspective, and this may eventually reduce risk when we […] think about the perspective of things went wrong. If you have something very well-tested, chances are that things will work better than other situations, when things are not so well-tested.”

As with financial risk, code writers sometimes choose their error handling level intentionally. For instance, BJ (an HFT software developer) stated that often, due to trading opportunities, he writes intentionally a code with a failure probability, which is greater than the ideal:

BJ: “My perspective was that, you know, giving some change that a trader wants to incorporate into the system, am, is going to cost a certain amount of […] time and material, developer resources and so on. Now, often […] if I wasn’t operating that environment, I was
just a part of the technology organisation, I may say: this is the best way to do it, and it’s going to cost you three months, and I would just get on and do that work. But when you are sitting with them you see that there are opportunities which are only there today, you need to make, take those opportunities, and even if there is a risk of failure, that may be an acceptable risk, for the up-side [...] It’s an interesting angle. As a developer I always think in terms of, I want to build my software so that it will never fail, but sometimes, to build very fast software, you have to compromise and make it fragile. And it can fail. But it’s ok, so long as it’s working within a controlled environment, where failure is managed.”

**HFT practitioners exhibit individual differences in strategy preferences.** As with codes, HFT practitioners have identified individual differences in strategists’ age, education, experience, and skills (quotations Q1.15 and Q1.16). In addition, they emphasised the importance of individual differences in strategists’ beliefs about the markets (quotation Q1.17), the extent to which they use financial literature in their strategies (quotations Q1.18 and Q1.19), and the extent to which they use novel methods (quotation Q1.20). Indeed, in human trading contexts, beliefs about the behaviour of the market have been found to influence stock prices (Friesen, Zhang and Zorn, 2012). In HFT, beliefs about the market determine the models that strategists use. For instance, HU (a senior quantitative trader), believes that the market cannot be realistically modelled and therefore prefers strategies which do not attempt to explain its behaviour:

HU: “Algorithms vary and some actually give you insight [about the market], right, they tell you: if that coefficient is that, you know, that means the market is like this. I don’t – my algorithms are more [similar to] a black box. I, ideally, I would like to learn something from them, but if I have the choice of having a good model that works, and a bad model that teaches me something, right, I would go for the black box model if it works. And, usually, you can’t have both [...] Finance is a very empirical science. Often you find something, you have no idea why it works, am, right, and you will never know why it works [...] I don’t even want to know what the algorithms is doing, because it only distracts you. There is nothing to learn
from it [...] and I know others, they like talking about the market data and Bloomberg [...] I think it is stupid, I think it adds no value.”

As with human financial decision making (Berrada, Detemple and Rindisbacher, 2018; Bodnaruk and Simonov, 2016; Kupiec and Sharpe, 1991), HFT strategists exhibit individual differences in risk behaviour. Specifically, strategists differ in the extent to which they are risk averse (quotation Q1.21). TF (a CEO of an HFT firm) expressed his insights about differences in strategists’ risk aversion as follows:

TF: “So, for example, ah, when I was talking about cowboys, I called “cowboys” and “elder cowboys”. Those guys are very risk tolerant, so they can put risks, take risks in their algorithms [...] The code cowboys and elder cowboys tends to take huge risks in their algorithms even if they sometimes break the corporate policy. For example, you have a [...] risk probability about 0.01 or 1%, they normally break it in their code. And that’s a cowboy [...] An owl is somebody very smart [...] They are much [more] risk intolerant, and they are very careful.”

HFT practitioners identified additional individual differences between strategists, including the asset classes they choose to trade on (quotation Q1.22) and the way they choose to affect other market participants (quotation Q1.23).
Table 1. Themes, concepts, and exemplifying quotations related to the dimension ‘HFT practitioners exhibit individual differences, which are related to their performance’.

<table>
<thead>
<tr>
<th>Themes</th>
<th>Concepts</th>
<th>Exemplifying quotations</th>
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<tbody>
<tr>
<td>HFT practitioners exhibit individual differences in code writing</td>
<td>Age, education, experience, cognitive abilities, and skills differentiate between code writers</td>
<td>Q1.1. NL: “Now there is a new generation of coders - HFT or coder traders, that usually come from a much stronger background, so – I learnt on the job. [...] When I was a kid, I didn’t even know what Goldman Sachs was, I had no clue [...] But, there is a new generation that are Maths PhDs and, one of my colleagues is a PhD in Maths from Stanford and Post Doc in Maths from Harvard. [...] It’s a much stronger generation that comes, and, again, I think every generation builds on everyone else’s shoulders, so, it’s faster.”</td>
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<td></td>
<td>Education</td>
<td>Q1.2. HU: “If, I would say, someone has a pure maths background, he will opt for techniques that are theoretically correct, right. Whereas when you have an engineering background, you know, not aiming for mathematical correctness, but for, you know, “it works well enough.”</td>
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<td>Experience</td>
<td>Q1.3. AD: “[...] My experience and the tools I used at university and still like to use even though the world has moved on and the guys have faster tools for doing stuff. I like to be – you know Unix? That’s what a lot of the high frequency engines are built on. So, I like to use that kind of technology and the command line, just doing things with text.”</td>
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<td>Cognitive abilities</td>
<td>Q1.4. YR: “Some people have a better way of dealing with very complex problems than others, and some people are very, am – they write a lot of code when they don’t need to [...] But [...] you know, there are more elegant ways.”</td>
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<td>Skills</td>
<td>Q1.5. HU: “On the coding side, there are very different skill levels, so [...] the, sort of, proportion of people who can actually write good C++ code is actually fairly small.”</td>
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<td>Code writers differ in their coding preferences, style, and clarity</td>
<td>Q1.6. RC: “So, for example, am, I don’t use open source code, I write everything myself.” Q1.7. OS: “We all have our own style of writing code, and the things we are used to, and things we are considering beautiful code.”</td>
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<td>Coding preferences</td>
<td>TG: “If you are writing in C, someone likes declaring a function at the beginning, or someone like defining global function, just using pointers [...] C++ is more flexible. C++ not only has structs,</td>
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it has classes … Some prefer using references and some still prefer using raw pointers, like C, and it’s all different … You can put a function in a struct and this is quite different from C, and someone likes it, someone doesn’t like it, someone likes design one class or one struct …; someone thinks: I could [use] two variables doing something you could put into one class … Someone likes putting them together. Someone may think, the logic of your design with two variables – no, no, no, this variable should be combined with the other one …] Even in C, different people use different style [for] coding. So, in C++ it’s more flexible.”

Clarity
Q1.8. PL: “Anyway, code in my very strong opinion is not just about what the computer will do, it is what’s written for people to understand and improve upon it. That’s code. That’s, and because of that thinking about code, it’s not only what is executed by computer, but also what people will read, to be able to improve upon it, it’s very much I am trying to write code that people can read and can understand […] I am trying to make the code such that the relations between parts are visible. Maybe not always obvious, but visible. On the other hand, I have colleagues who just write flow of many many lines of code just to achieve a goal, which they do, but then it’s pretty tricky to understand how they got that point. Am - a different approach. It’s a really different kind of thinking about code.”

| HFT practitioners exhibit individual differences in error and exception handling | Code writers differ in the extent to which they consider exception handling important | Q1.9. DV: “I usually check exceptions very carefully. Because always I worry about if my programme crash […] My programme can cause loss, so I check every exception in my code very carefully. So, in this way, it takes much more time to code and test my programme. In my… in this company, sometimes I spend a lot of time to develop my programme, and my manager even challenged me that on that: “Why you spend so much time to develop the programme?” And “other people can finish a single programme very quick”. And sometimes I told him that I need to handle the exceptions very carefully, I need to do more tests to make sure it didn’t crash, it didn’t cause loss, and sometimes my manager said: “It’s not that necessary. You shouldn’t test it that carefully.” |
| Code writers differ in their debugging skills | Q1.10. NL: “Debugging is a very critical thing. It’s a very specific skill set. I am not good at it. Some people are amazing debuggers.” |
| Code writers differ in their failure | Q1.11. YR: “Because people are very different, and one person’s test for something may not be exactly as good as it should be, you know. […] All probabilities in code about testing are really anecdotal probabilities. They are what a person decides is, ah, the possibility or the probability, personal probability of a
likelihood assessment

failure. So [...] you want to make sure that you get as many views on that as possible. Otherwise, [...] they might have a [...] lower probability of their interpretation of the likelihood of failure than is reality. Just because they are more risk averse or less risk averse person.”

Code writers differ in the extent to which the code they write is defensive

Q1.12. XM: “I guess mistakes are a part of the personality, right [...] because some people would be more pessimistic than others [...] So someone would think to himself “well, this kind of scenario can happen, I can code for that,” other people would think: “oh no, that could never happen, that’s just too unlikely, that’s just too catastrophically wrong, it can’t possibly happen,” and they are not going to code for that [...] defensive coding [...] it’s called.”

Q1.13. BJ: “I guess the question would be what is the difference between code that I write and some else writes, presumably you ask us to solve the same problem, with the same design constraints etc, right. Now, the interesting thing is, when someone gives you a problem, they give you, ah, you have to kind of read between the lines a bit, like, they are not stating the obvious, or what they may consider the obvious. So, after you have gained some experience as a developer, you kind of build more intuition to the kind of things which can go wrong. And you might be more inclined to code defensively, especially, for example if you [...] have got support responsibility, so you may be called in the middle of the night, to support the operation team.”

Q1.14. XM: “Some people relay on the safety net of other people’s ability to write code which will catch a failure scenario. And they lost a hundred of millions in five minutes, and that’s a painful loss to settle [...] So, I guess that’s another aspect of personality, isn’t it, your belief that you are a part of a team, and that, maybe, that team, that you thought, is probably more defensive than you are, would bail you out.”

HFT practitioners exhibit individual differences in strategy preferences

Age, education, experience and skills differentiate between HFT strategists

Q1.15. TF: “So, when you are a new comer, a new blood, or just a new bastard, or a young bastard who has just graduated from his, ah, school, and just recently received his fancy shmancy pedigree, ah, he tries to implement new things [...] They try to implement risky, untested, or even unpublished algorithms. They may fish out from academia different way, for example, from their own PhD programme or the programme of their friends, or guys from the faculty they may know. And they [...] tell their bosses, “look – it’s a very good idea. Let’s try it out”. And when they are questioned about the risk, their probability of success or the P&L expectations, they just [say]: “I don’t care,
let’s just try and see” [laughing]. So, those are young bustards, who just don’t care about somebody’s money and they are just risking for them. And, of course, those guys who are older and maybe more experienced, they [...] hate risk and they [...] are less risky.”

Skills
Q1.16. JC: “I can’t write a market making algorithm that can beat [...] Citadel or whoever.”

HFT strategists differ in their beliefs about the market
Q1.17. OG: “Ultimately, all the algorithms are based on common sense. [...] This is the one part which is not really mathematical. The basis of the algorithm, it’s like: I think that this particular thing is going to predict the future just a little bit. That’s in essence what any trading algorithm is going to do. It’s trying to predict what’s going to happen to the market [...] in the statistical sense. And either these ideas come to you, or they don’t. I mean, I think that there are lots of people with mathematical [background] that would not necessarily spot these things. Because, I think it’s probably a slightly distinct skill.”

HFT strategists differ in the ways they use academic literature
Q1.18. SG: “If the price was ending with 5 or 0, I knew that, for example, if we were to reach this point, and cross this point, so you switch, for example to 51, I know the market would probably move more than averagely to 55. And if the 55 it would cross, I know it would move to 60. And if the 60 it does not cross, I know it would move back at least to 55 [...] because screen traders and traders, they enter the price in the market – they enter round number. That’s a bias. They finish by a round number.”

Q1.19. No use of Behavioural Finance theories:
HU: “No, not usually Behavioural Finance, right, because, when you look at those papers, right, they go over years and years of data. Right, and then they find some small effect. So, it works, but over a long period, and that is not HFT. So, the other thing that proper HFT literature [...] like order-book dynamics and things like that, but it’s fairly academic, right, the model they present are – all the back-tests, they are either not realisable, or the models are so complicated, that it would be too slow in practice. Because in HFT, there is no point in being right, but being too slow. It’s better to be somewhat right but fast enough [...] I am more interested in this optimisation mathematical papers, that tell you how to optimise – things like that. So, it’s more the maths computer science side.”

HFT strategists differ in the extent to which they
Q1.20. YZ: “Yes, my colleagues are slightly, like, more daring than me [...] so, they may have new methodologies that I haven’t yet from a class that I am not confident with.”
HFT strategists differ in the extent to which they are risk averse

Q1.21. XM: “[I am] reasonably risk averse, more so than a lot of people I worked with.”

HFT strategists differ in the asset classes they choose to work on

Q1.22. OG: “In the company I traded for, I was working for last, my colleague would have been trading something else. A different asset class. So, in the high frequency world, that’s really important because in different asset classes, like in equities, you get much more information from the exchange about what’s actually traded, whereas in FX you don’t really get very much information about what is traded at all.”

HFT strategists differ in the ways they choose to affect other market participants

Q1.23. OS: “I would say [...] because another will have some level of risk-taking, is very aggressive algorithm or very passive, or [...] smash the market and really don’t care about the effects, just get out of it as fast as possible, or, do you try to actually be kind to your counterparts on the market and not behave in – nothing unethical by the way, but clumsy way, selling your portion of something in the market - you can do it in so many ways. And some of them are more sophisticated and more [...] stealthy than other ways, which are very, very like, blunt. And especially in a market like FX, market where there are so many direct relationships, so, if I mistreat a liquidity provider, he will most likely turn me off. So, it’s a self-fulfilling prophecy, if you behave badly, you will be cut off [...] and nobody will want to trade with you. And that’s not really the case in equities. Right, it’s a different ball game. But, yes, I would say the personality of the developer [...] will be reflected in the algorithm.”
Organisational and individual practices affect HFT similarities

Three themes gave rise to the dimension ‘Organisational and individual practices affect HFT similarities’: ‘A proportion of HFT firms employ organisational practices that encourage code and strategy similarities’, ‘A proportion of HFT firms employ organisational practices that do not encourage code and strategy similarities’, and ‘Certain personal practices encourage code similarities’. Table 2 presents concepts and exemplifying quotations, and all the quotations referred to in this section are presented in it.

A proportion of HFT firms employ organisational practices that encourage code and strategy similarities. A few HFT practitioners stated that there were similarities between HFT practitioners and attributed these similarities to the hiring procedures employed in HFT firms (quotation Q2.1). For instance, HU (a senior quantitative trader) has noted that job specifications ensure that HFT practitioners have similar cognitive abilities:

HU: “I think, to a large degree, we are very similar personality-wise. It is a very homogeneous workplace. I mean, not [only] ethnic, even ethics or gender-wise, but also mind-set wise.
Because [...] it’s not like in business or management, where you bullshit your way through; the system you are working on – it’s a very good filter, it kind of homogenises the workforce, [so that practitioners have] very specific skills and mind sets.”

Furthermore, some HFT firms employ job rotation. Due to job rotations, different practitioners work on the same system, and hence the expression of individuals’ unique personalities is limited (quotation Q2.2). In addition, a proportion of participants emphasised that their firms encouraged code similarity through peer reviews, testing procedures and controls (quotation Q2.3). As YR (a senior HFT software expert) stated, these practices sometimes aimed at reducing the effects of individual differences on code errors:

YR: “What you will have, to get rid of personality in code completely, is you will have redundant systems written by different people. And that’s probably the best way to describe
how you would do it. So, for instance, I had two risk engines on my front end, one written in one language by one set of developers, and one written in another language, by a different set of developers, and they were in series. So, for this very important part of the code, which is the risk engine for the execution, it had two checks by independent [codes]. So, if you think of it statistically, you have got, you know, you have got independent probabilities of failure. So, you can actually multiply them together. Again, it’s not quite like that, because it’s the real world, but, you know, that’s the theory behind doing a thing like that. So that’s how you get rid of personality in code. But there is always personality in code.”

YR mentioned also that certain firms imposed strict coding standards, regulating the way the code is written. Similarly, EO (a senior HFT software engineer) emphasised that tests limited the expression of the human aspects of the industry:

EO: “Because the strategies that you develop, first of all, they are not over night, ah, you know – it’s a research process that extends over weeks or months. Sometimes, for years [...] But also, you know, before you [put anything to production], you back-test it, it’s a real scientific method [...] So, if there is any emotional component there, I think it is taken out by the rigor of the process.”

Finally, a few participants have noted that in some HFT firms, risk level is tightly regulated, and therefore individuals’ risk propensity may not be fully reflected (quotation 2.4).

A proportion of HFT firms employ organisational practices that do not encourage code and strategy similarities. In a proportion of HFT firms, HFT practitioners work by themselves and no peer reviews are conducted (quotation Q2.5). However, in companies which use this practice, peer-reviews often focus on superficial characteristics of the code (e.g. variable names; quotation 2.6).

Furthermore, comments given during peer-reviews sometimes reflect self-serving bias (Sidle, 2009). NL (a lead quantitative HFT infrastructure developer) has expressed this idea:
NL: “There may be egos involved [in peer reviews.] [...] One thing where this shows is that you think that everyone else’s code is rubbish, except for your own. [...] So, when I see actually code, I say – “well, actually it’s not rubbish [...] I should respect [it]”. But, in addition to that, there is often the case, that I almost always want to touch someone else’s code, as in, change this or change that, or do whatever [...] and I receive the same from the other people. Like, when they see my code, they say: “OK, it’s decent, but I will change this or change that”.”

Certain personal practices encourage code similarities. HFT practitioners often express the will to learn or to be inspired by other practitioners (quotation Q2.7). For instance, RT (an HFT quantitative strategist) appreciated the opportunity to learn from his colleagues:

RT: “I think I have a lot to learn, and I think I am in a fantastic place, where I can learn more from the people around me.”

In addition, a few practitioners stated that they considered it beneficial to adapt their coding style to that of the existing HFT systems (quotation Q2.8).
Table 2. Themes, concepts, and exemplifying quotations related to the dimension ‘Organisational and individual practices affect HFT similarities’.

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<thead>
<tr>
<th>Themes</th>
<th>Concepts</th>
<th>Exemplifying quotations</th>
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<tbody>
<tr>
<td>A proportion of HFT firms employ organisational practices that encourage code and strategy similarities</td>
<td>Some HFT firms encourage employee similarity through hiring decisions and requirements</td>
<td>Q2.1. XM: “Typically, if you are already in a team, and you have got that attitude, you get hired because of your similarity to the other people [who are] already in the firm. That’s a part of the culture. So […] if the hiring manager likes to risk, and does not think defensively, then the odds are that he is going to employ more and more people like that.”</td>
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<td>Some HFT firms encourage code similarity by job rotation</td>
<td>Q2.2. VX: “In previous work we rotated on modules of a system a lot and as a result, different modules were similar.”</td>
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<td>Some HFT firms encourage style similarity through peer reviews, testing procedures and controls</td>
<td>Q2.3. BJ: “The guys I am working with now – there is a lot of effort put into making things consistent, lots of peer reviews, so before any change goes on to the Master […] which is the one which finds its way to production, […] even on the development side, there are tight controls […] we expect to have, maybe one author, but many different eyes on. […] because that’s kind of a static analysis, people are going over it, asking questions, how does this work, and that kind of, I guess, encourages people to have a consistent style.”</td>
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<td>In some HFT firms, risk level is highly regulated</td>
<td>Q2.4. RT: “Crossing above your risk level in the organisation of the [bank name] is – I would say it, ah, without any doubt: impossible. The amount of different layers within the organisation that prohibits you [from] going beyond that risk level is so robust […] that it’s almost boring in some ways.”</td>
</tr>
<tr>
<td>A proportion of HFT firms employ organisational practices that do not encourage code and strategy similarities</td>
<td>Not all HFT firms employ peer reviews; in some firms, practitioners work by themselves</td>
<td>Q2.5. XM: “[In the bank […] it was very much the case, that you would write a piece of software and it was up to you to test it and you take full responsibility. So, the code very much reflected your personality, your ability and inability to think logically.”</td>
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<td>In a proportion of HFT firms, peer reviews do not examine all aspects of the code or the strategies</td>
<td>Q2.6. VR: “It’s a pity, really, because, you know, either you confess that you don’t understand and […] you are not afraid, or you make sensible comments, like “oh, be aware, cause that’s going to break something, right, that functionality should not be written like that, that should be different” […] And the comments that I get are just like “oh, I don’t really like that variable name, could you make it [different]?” For instance, we got a bunch of services, right, and our services are always called “something something service”. And, in order to shorten the names a little bit, I have called it “something something svc”</td>
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instead of "service". Because the big name was already pretty long. And [...] somebody put a comment saying: “could you replace svc by service please?” “OK, I will do it if it makes you more comfortable. But please pay attention to the logic, because there is a lot more going on there than actually the names of the variables.”

| Certain personal practices encourage code similarities | Practitioners affect each other’s code and strategies by teaching and inspiring | Q2.7. OG: “You learn something from somebody else, who says, that’s not a good way to do it. So, you think, oh yea, the way you have just explained is better. So, therefore, you implement that yourself.” |
|-------------------------------------------------------|---------------------------------------------------------------------------------| Q2.8. BJ: “If they [code writers] are good, they should be fitting to the surrounding code, they adapt like camelinias to the code that surrounds them. They will say: “OK, on this project we use some kind of style, I will do my best to fit in.” |

A proportion of practitioners adapt their coding style to that of the existing systems.
HFT reflects individual differences between HFT practitioners

Three themes have led to the formulation of the dimension ‘HFT reflects individual differences between HFT practitioners’: ‘One can identify the person who wrote a code or his/her personal characteristics by reading his/her code’, ‘HFT code reflects characteristics of the code writer’ and ‘HFT strategies reflect characteristics of the strategists’. The concepts, that have given rise to these themes, and exemplifying quotations are presented in Table 3, and all quotations in this section refer to it. In total, 20 of the 30 participants positively answered the question, whether the code they wrote reflected their personality. Four participants gave inconclusive answers, and the remaining – negative answers.

One can identify the person who wrote a code or his/her personal characteristics by reading his/her code. A proportion of the participants stated, that they could identify code writers or their characteristics based on their coding style (quotation Q3.1) and the ways they used the programming language (quotation Q3.2). For instance, YR (senior HFT software expert) has stated that he could recognise code writers:

YR: “You know, you can read somebody’s code and see their thumbprint on it, you know, you just see that fingerprint generally. You know who has written the code even if they haven’t necessarily put their name on the top […] it’s just like reading somebody’s handwriting. You can, you know, if you work with somebody regularly, you know, you can see how they […] name variables […] There are companies that do strict coding, am, standards they call them, where you would be told how you write variables […] But if you are not in one of these firms, it’s quite easy to see.”

HFT code reflects characteristics of the code writer. Many participants asserted that HFT code reflects characteristics of the code writers. Specifically, they mentioned the coder writer’s age, education and experience (quotations Q3.3, 3.4 and 3.5), the coder’s intelligence and sophistication (quotation 3.6), the coders’ methodology and perfectionism (quotations 3.7 and 3.8) the coder’s
ability to write codes that are fast (quotation Q3.9), the coder’s writing style (quotation Q3.10), the
coder’s understanding of what a good code is (quotation Q3.11), the coder’s desire for short
term results and interests (quotations 3.12 and 3.13) and the code writer’s order preferences
(quotations 3.14). For instance, TG (a HFT software engineer) expressed the idea that his code
reflected his style as follows:

TG: “Yes, at least I suppose. My friend told me [laughing], my team mate told me, “oh you
write code in so violent way [...] It’s solid, but, you know, very, how to say that, violent! [...] My
friend likes elegant codes, and I like coding straight [...], codes that go straight; I don’t design
any fancy stuff, just go straight. You can see clearly what I want to do in the codes; and
sometimes I make some tricky codes and they can easy understand: “oh, you want to do that”
[...] Writing codes in C++ is art! It’s just like you are painting, you are drawing a picture, it’s not
like [taking a] photo [...] C++ is a language, it’s art! It’s art! [...]”

In C++ you [...] can make it [the code] more beautiful, some codes are really beautiful, and my
code looks like a man with muscles, not a girl [...] If you are coding in C++, if you have several
years programming experience on C++, you can definitely tell the difference between these
different code styles.”

HFT practitioners perceived HFT code to reflect also the code writer’s error handling and precision
approach (quotations Q3.15 and Q3.16). For instance, VR (HFT trader and programmer) stated that
the code he wrote reflected his accurate exception handling style:

VR: “I think, yes, I think it can reflect my personality in the sense that I am very [...] cartesian
[...] From Descartes. Well, meaning that I am very, sort of like, scientifically driven and very
precise and detail-oriented and very strict, see what I mean? So, when I am writing code,
amm, I always, so like, thinking about edge cases, and always make it very, very strict. It’s very
hard to describe. It’s almost mathematical, right [...] I am not leaving any room for any, sort of
like, you know, randomness, or [...] random behaviour.”
**HFT strategies reflect characteristics of the strategists.** HFT practitioners have stated that HFT strategies reflect the strategists’ intelligence, sophistication, and cognitive abilities (quotation Q3.17), strategists’ assumptions or beliefs about the market (quotation Q3.18) and strategists’ risk preferences (quotation Q3.19). For instance, SG (the head of technology of an HFT firm) has considered assumptions about market efficiency and the related distributions to be human biases, which were reflected through HFT strategies. He summarised his views as follows:

SG: “You say: “Oh, this is my mathematical model, so the market behaves like that”. No, it does not work like that […] Then you transfer it to your model. So, there is a lot of bias like that.”

HFT practitioners perceived HFT to reflect also other personal characteristics, including their approach to code clarity, daily experiences, lifestyles, agility, preference for code automation, responsibility, and approach for relationship with other market participants. Furthermore, many participants emphasised the role that human traders have in monitoring HFT.
Table 3. Themes, concepts, and exemplifying quotations related to the dimension ‘HFT reflects individual differences between HFT practitioners’.

<table>
<thead>
<tr>
<th>Themes</th>
<th>Concepts</th>
<th>Exemplifying quotations</th>
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<tbody>
<tr>
<td>One can identify the person who wrote a code or his/her personal characteristics by reading his/her code</td>
<td>One can identify code writers based on the coding style</td>
<td>Q3.1. TG: “Different people have different coding style, and […], at least [in] my team, it is very easy to tell which code is mine. The style is very clear. Maybe the whole structure […], architecture of the system, if you consider it as a building, it’s solid, it has some rules, but inside, how you decorate your own room, it’s quite different. So, I can easily tell, ok, this part of the code is written by who.”</td>
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<tr>
<th>HFT code reflects characteristics of the code writer</th>
<th>HFT code reflects the coder writer’s age, education and experience</th>
<th>Age</th>
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<td>Q3.2. RC: “Funny enough, I can read code and tell the mood of the [code writer] - I kind of, get a good idea into the mood of the way somebody thinks. And their state of mind. You know, where they are putting – whether they have been interested in the code, whether they have been really safe […] I mean, for me, coding is poetry […] Looking at the code, I can understand so much about the coder. I can understand – I can probably guess his age, I can guess which language – so, obviously, coders can write in various languages. So, for example, you have got a language like Java, which is - everything is an object. So, you have lots of classes and what not […] There is a certain style of coding – Java promotes that coding. If you are older, like I am, I mean, I first learnt how to code in Assembly language. So, the code I write is much more like C++ than Java. So, as soon as I see a bit of code, I know that this person is experienced in Java. Therefore, that person, is typically between 30 and 35. And I can tell how much experience the person has got as well, because there are certain shortcuts you make, certain things that you don’t do. I can tell if someone is as old as me, because they will probably write in a similar style. I truly will.”</td>
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<td>Q3.3. NL: “[I am able to distinguish between] people who worked in HFT from people who didn’t. It’s – glancing, I will tell you whether this person has worked in the industry before or not, and I can get the age by 5 or 10 years, because […] I code games and actually a lot of my friends are gamers, or game developers. […] There is a certain maturity that goes in code. It’s kind of like sports […] or piano players […] So, you know, in the beginning it’s all about practicing all the basics, so that you, you know, it comes out of you naturally. And then there is a certain tendency to […] show off. And later, it’s stripping down to bare essence. You know, you don’t have to flourish […] you try to become... back to basics, or something like that. I see that in other sports as well […] I rediscovered ballet dancers recently. In the beginning it is all about raising the leg as high as possible. But then it became the movement of a finger, the nuance of the fingers […] so, I think it is something to do with the craft after a certain number of years more so than HFT.”</td>
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Education
Q3.4. YZ: “throughout my years of experience I have definitely found methods and methodology indeed that I find particularly pleasing to use. So, [...] I guess you could say that it reflects my personality, but it is based on what I have learnt and what I have read in books. It’s something I do, what have learnt.”

Experience
Q3.5. YR: “You also see people backgrounding code as well. I mean, if you have got someone who has been doing a lot of coding in computer games, and moved into, for instance, the high frequency trading, then you will see tricks that they used in computer games in terms of bit flipping and the various techniques to speed things up. You could see it in there. You see people ordering layouts of data structures to take [...] advantage of what you would call cache coherence and things like this. So, am, yea, absolutely. So, ah, and there are other people who are used for very – I am going to say Microsoft way of doing things. You know, it’s very obvious, again, because they follow all the logical steps, and it’s very ordered [...] I mean, you can see it.”

| HFT reflects coders’ intelligence and sophistication | Q3.6. JC: “The code that I write [...] would not just do what it is meant to do. It would find some tricky way of doing it with less steps, so it’s easy to take something that has been done, turning it into code and it’s all fantastic. The hard bit is – ok, but if you wanted it to be faster, what are the edges you can shave off, without actually impacting what it does. So, finding new uses for things which were designed to do something completely different, and saying, I can actually use that to speed things up, so, I can store information. Just one example is, you might be able to say, OK, when the market ticks up, I am going to run this calculation and decide whether I am buying. Or, someone has tried to hack for speed will actually say before the market has ticked up, I am actually going to do a calculation, yea, before the market ticks, I am going to run a calculation trying to say if the market goes up, or if it stays, or it goes down, what am I going to do. So, you basically run through some scenarios in advance, so that when it happens, you have got the answers sitting right there. So, if you are then competing against another algorithm, which isn’t doing that, well, you are going to beat it. Every time. Because you have worked out the answer in advance.” |

Methodology
Q3.7. SK: “I would say that the way I think things out, am, is reflected. I try to, am, I am quite methodical in my approach to things, so, I hope that, you know, shows in the code as well, that it is methodical and obvious how it’s working. That’s what you are always aiming for, that something is simple and obvious. So, I aim for that, yes.”
<table>
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<th>Q3.8.</th>
<th>DV: “I think that it reflects that I always try to do things perfectly and I don’t want to make mistakes and I don’t want other people to say that they don’t have the ability to do the thing good.”</th>
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<tbody>
<tr>
<td>HFT code reflects the coders’ ability to write codes that are fast</td>
<td>Q3.9. SK: “Yes! Yes, there is! There is a lot of variations in development. In our company we have a lot of, am, junior developers and senior developers. So, there will be obvious differences there in am, they may not know the right way or the fast way to do something. Am... they may not always know the performance techniques. So, there might be slow areas in their code.”</td>
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<td>HFT reflects the coder’s writing style</td>
<td>Q3.10. YR: “Different people have different ways of, ah, writing code. And yes, you can see that, you can see that, generally. But you have to work with people for a long time.”</td>
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<td>HFT code reflects the code writer’s understanding of what a good code is</td>
<td>Q3.11. BJ: “My solution may differ, it is probably going to differ based on my past experiences and what I value as a developer, what I think is the key attributes to a good system, compared to someone who has, maybe, grown up in a different environment with different constraints.”</td>
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<td>HFT reflects the coders’ desire for short term results and interests</td>
<td>Q3.12. LQ: “I think… Maybe yes because the reason I go into, because I actually have [...] I usually focus on short-term profit [...] yea, so it reflects my personality [...] because I want to see the short-term results instead of waiting years. For example, in hedge funds [...] you always [wait] for years or half years.”</td>
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<td>HFT reflects the code writer’s order preferences</td>
<td>Q3.13. BH: “I really, really like our finance, I really find this subject really, really fascinating. This is why I am here, this is why I crossed the ocean to be here [...] I find it really fascinating.”</td>
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<td>HFT reflects the code writer’s error handling and precision approach</td>
<td>Q3.14. PL: “I try to make it organised. I am not sure I am such an organised person, my wife will say probably that I am not. But I try to make my code organised. And my desk is actually pretty organised as well, it’s normally like that, it’s am – not very messy. So, am, at least in some aspects of life I try to be organised and that includes code.”</td>
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<td>Q3.15. OS: “I would say, that’s more the analytic side, it reflects my analytic side, to be very thorough with what I am doing and not making any mistakes, because making mistakes – [if you do them] manually, it’s one mistake, if you do it with the computer, that might multiply into 1000 very, very quickly.”</td>
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<td>Q3.16. TG: “I prefer second order accuracy or fourth order accuracy of the numerical method [...] But my friend, he said: “come on, it’s the finance world! For the dynamics you just need the first order, let’s put it up [that way] [...] In our work, algos for this industry, most of the algos of models are that it does not matter, there are random errors or trunc[ation] errors, you can’t even know it. Second order accuracy [...] is good enough. It’s really good enough [...] It’s good heart.”</td>
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<tr>
<td>HFT strategies reflect characteristics of the strategists</td>
<td>HFT strategies reflect the strategists’ intelligence, sophistication, and cognitive abilities</td>
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<td>HFT strategies reflect the strategists’ assumptions or beliefs about the market</td>
<td>Q3.18. SG: “I think that there are some biases, that are passed to some strategy definitely. Because strategies are based on some assumptions that you make, and the assumptions are basically biased. So, yea, you will have some transfer of assumptions to the system.”</td>
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<td>HFT strategies reflect the strategists’ risk preferences</td>
<td>Q3.19. JC: “From a risk-taking perspective it [my strategy] certainly does [reflect my personality]. That it takes zero risk. So, yes, it does reflect my personality in that sense.”</td>
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**Additional analysis: Metaphor and simile analysis**

Metaphor and simile analysis revealed that HFT practitioners often describe code writing as a form of art or literature. For example, NL (a lead quantitative HFT infrastructure developer) said:

> NL: “I would read code in the same way that I would appreciate literature [...] The same way that I would appreciate Dostoyevsky or Dickens or someone else.”

Similarly, RC (the director of an HFT company and a software developer) said: “for me, coding is poetry” and BH (a senior software developer) said: “It’s like an art”.

Furthermore, a proportion of HFT practitioners attributed to HFT or to their work human characteristics. For instance, JC (HFT software architect) compared the process of HFT code development and running to raising a child:

> JC: “it’s a little bit like, am, raising a child, and then watching that child, kind of, operate in the world. You are thinking about all the things you have told it to do and not to do and wondering whether you have thought about everything. But, you also know it’s too late, you have set this algorithm in motion, and if it does do anything wrong [...] you can’t do really anything. All you can do at that point is watch and see what’s going on.”

**Conclusion**

This study has examined HFT-related individual characteristics that differentiate between HFT practitioners (Research question 1), organisational practices that increase the similarity of HFT (Research question 2) and the ways in which HFT reflects individual differences between HFT practitioners (Research question 3). Analysis was based on the contents of 30 interviews with HFT practitioners.

Answering the first research question, this study has identified a list of individual differences between HFT practitioners. HFT code writers differ in their age, education, experience, cognitive
abilities, skills, coding preferences, style, clarity, the extent to which they consider exception handling important, their debugging skills, their failure likelihood assessment, the extent to which their code is defensive, and the extent to which they rely on the safety net, that their team members provide them with through their codes. HFT strategists differ in their age, education, experience, skills, beliefs about the market, the ways in which they use academic literature, the extent to which they use novel methods, their risk aversion, the asset classes they choose to trade on, and the ways in which they choose to affect other market participants. Some of these individual differences have been studied before. Specifically, practitioners’ education, experience, and risk preferences have been shown to affect financial behaviour in non-HFT contexts (Anderson, 2013; Bodnaruk and Simonov, 2016; Field and Mkrtchyan, 2017; Li, Zhang and Zhao, 2011). However, previous literature has not explored individual differences in code and strategy writing.

Answering the second research question, this study highlights central organisational practices, which increase HFT similarity. In particular, it suggests that hiring processes of HFT firms contribute to the similarities between HFT practitioners and, thus, also to HFT similarities. In addition, it suggests that job rotations, peer reviews, testing procedures and controls increase HFT similarities. Regulation of risk level increases HFT similarities, too. However, practitioners do not perceive these measures to be always effective in inhibiting individuals’ personality expression in their code. For instance, comments given in peer reviews may refer only to narrow aspects of the code or peer self-serving bias. Furthermore, not all companies employ these practices. For example, in some HFT firms, there are no peer reviews. This study identifies also personal practices that increase HFT similarities, including teaching, inspiring, and adapting personal writing styles to the styles of existing systems.

HFT literature has contributed important insights and empirical findings into HFT similarities (Benos, et al., 2017; Chaboud et al., 2014). However, they neglected the effects of organisational practices. Research on the mirroring hypothesis has showed that organisational characteristics are reflected through organisational products (Cabigioso and Camuffo, 2012; Constantinides, Henfridsson and Parker, 2018).
Answering the third research question, this study reveals that many individual differences between HFT practitioners are reflected through HFT codes and strategies. Specifically, HFT codes reflect the code writers’ age, education, experience, intelligence, sophistication, methodology, perfectionism, ability to write codes that are fast, writing style, understanding of code quality, desire for short-term results, order preferences, error handling and precision approach. HFT strategies reflect the strategists’ intelligence, sophistication, and cognitive abilities, their assumptions and beliefs about the market, and their risk preferences. In fact, most participants agreed that their codes or strategies reflected their personality. Furthermore, a proportion of the participants stated that they can identify code writers, or their characteristics, based on code style and the use of programming language.

The results presented here are in line with research about code writers’ personality and personality expression in stories and social media texts. Research about code writers’ performance has demonstrated that their personalities affect software quality and code writers’ behaviour (Acuña, Gómez and Juristo, 2009; Capretz, Varona, and Raza, 2015; Yilmaz et al., 2017). Studies about personality expression in stories and social media texts have shown that people’s stories and tweets convey information about their personalities, which can be used to accurately learn about the personality of the person who wrote the stories or messages (Küfner et al., 2010; Orehek and Human, 2017; Qiu et al., 2012). This is especially relevant to the case of HFT, given that metaphor and simile analysis has revealed that many HFT practitioners consider their work a form of literature or art. Therefore, this study extends HFT to the study of individual differences. Challenging the perception that HFT has a mechanical nature, it portrays HFT as a form of trading which is conducted by machines with human attributes – androids.
Applications

Financial modelling applications. Financial studies have tended to employ a mechanistic approach for HFT modelling. For instance, a classical study has used risk-neutral agents to model HFT (Kozhan and Tham, 2012, p. 2133). Whereas the financial literature has contributed numerous important insights about HFT, this study suggests that HFT encapsulates some of the characteristics of the people who wrote its codes and strategies. Thus, it suggests that HFT models should take into account individual differences between HFT practitioners. Market models with heterogeneous HFT agents may be more realistic than existing models.

Management applications. Individual differences are thought to affect a wide range of employee and firm performance measures. For instance, personality has been shown to affect productivity (Cubel et al., 2016), person-organisation fit (Ostroff, 2012), and firm competitive advantage (Schneider and Bartram, 2017). This relationship has been attributed to employees’ intrinsic motivation (Segal, 2012) and decision-making (Apesteguia, Azmat and Iriberri, 2012). In financial contexts other than HFT, it has been demonstrated that individual differences affect financial behaviour (Lemmon and Ni, 2014). However, to the best of my knowledge, no studies have examined the direct effect of individual differences between practitioners on the characteristics of their products. This study reveals that, in the context of HFT, individual differences between practitioners affect their codes and strategies. This observation could be used to enhance personnel selection processes.

Limitations and future research

This study has answered the key research questions. However, as a first study on individual differences in HFT, it has employed qualitative, subjective research methods. HFT research has started employing qualitative methods (Mackenzie, 2018). In addition, research has established that employees’ subjective performance measures are correlated with objective performance measures.
Nevertheless, I consider it important to complement this study by examining individual differences in HFT using quantitative research methods.

Previous research has often disregarded the effect of organisational practices on HFT. This study suggests that hiring procedures, firm rules and peer-reviews influence HFT codes and strategies. Thus, it encourages further research about the relationship between organisational practices and HFT. For instance, participants in this study have expressed mixed opinions about the efficiency of peer-reviews. Studies have shown that the way feedback is administered affects performance (e.g. Kuhnen and Tymula, 2012). Thus, future HFT research could examine the question, whether companies which employ peer-reviews are more successful than others, and which feedback methods are most effective.

This study has demonstrated that individual differences in HFT practitioners affect the codes and strategies that they write. However, code writers and strategists work also in non-HFT firms in the algorithmic trading industry. Research has not examined the expression of individual differences in algorithmic trading practitioners on their codes or strategies. Given the results of this study, I hypothesise that individual differences would affect algorithmic trading, too. Testing this hypothesis could enhance the understanding of the modern financial industry.

This study has not examined the effect of the marital status of HFT practitioners on the code and strategies they write. However, a study about the effect of marital status on risk behaviour has found that, compared to married CEOs, single CEOs tend to choose more aggressive investment goals, and that their firms have higher stock return volatility (Roussanov and Savor, 2014). Future research could check whether these results hold for HFT practitioners, too.

Finally, this study has not explored the influence of gender on HFT because the HFT industry is dominated by men. Indeed, a few participants have provided anecdotal evidence suggesting that only few women work as HFT code writers or strategists. A large body of research has found that gender affects competitiveness and that men are more competitive than women (Price, 2012;
Therefore, HFT gender imbalances may be due to differences in competitiveness. Future research could study the reasons for the lack of gender diversity in HFT.

Appendix

Table A. Participants’ identifiers, professions, and method of data collection

<table>
<thead>
<tr>
<th>Participant’s identifier</th>
<th>Participant’s profession</th>
<th>Method of data collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD</td>
<td>Senior HFT consultant and software developer</td>
<td>Interview; face to face meeting; conversation was recorded</td>
</tr>
<tr>
<td>BH</td>
<td>Senior software developer</td>
<td>Interview; Skype meeting; conversation was recorded</td>
</tr>
<tr>
<td>BJ</td>
<td>HFT software developer</td>
<td>Interview; face to face meeting; conversation was recorded</td>
</tr>
<tr>
<td>DV</td>
<td>Project manager and software developer at HFT firm</td>
<td>Interview; Skype meeting; conversation was recorded</td>
</tr>
<tr>
<td>DW</td>
<td>Senior software engineer</td>
<td>Interview; Skype meeting; conversation was recorded</td>
</tr>
<tr>
<td>EH</td>
<td>High frequency proprietary equity trader</td>
<td>Interview; Skype meeting; conversation was recorded</td>
</tr>
<tr>
<td>EO</td>
<td>Senior HFT software engineer</td>
<td>Interview; Skype meeting; conversation was recorded</td>
</tr>
<tr>
<td>FR</td>
<td>Trader and code writer</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>HU</td>
<td>Senior quantitative trader</td>
<td>Interview; Skype meeting; conversation was recorded</td>
</tr>
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<td>JC</td>
<td>HFT software architect</td>
<td>Interview; face to face meeting; conversation was recorded</td>
</tr>
<tr>
<td>LQ</td>
<td>Data scientist and ultra-low latency trader</td>
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</tr>
<tr>
<td>NL</td>
<td>Lead quantitative HFT infrastructure developer</td>
<td>Interview; face to face meeting; conversation was recorded</td>
</tr>
<tr>
<td>NP</td>
<td>Quantitative HFT researcher</td>
<td>Interview; Skype meeting; conversation was recorded</td>
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<tr>
<td>OG</td>
<td>HFT consultant and quantitative analyst</td>
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<td>OM</td>
<td>Director of an HFT firm</td>
<td>Interview; face to face meeting; conversation was recorded</td>
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<td>OS</td>
<td>HFT algorithmic trading developer</td>
<td>Interview; Skype meeting; conversation was recorded</td>
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<tr>
<td>PL</td>
<td>Vice president at an HFT firm</td>
<td>Interview; Skype meeting; conversation was recorded</td>
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<tr>
<td>RC</td>
<td>Director of an HFT company and a software developer</td>
<td>Interview; face to face meeting; conversation was recorded</td>
</tr>
<tr>
<td>RT</td>
<td>HFT quantitative strategist</td>
<td>Interview; face to face meeting; conversation was recorded</td>
</tr>
<tr>
<td>SG</td>
<td>Head of technology of an HFT firm</td>
<td>Interview; face to face meeting; conversation was recorded</td>
</tr>
<tr>
<td>Code</td>
<td>Role</td>
<td>Method</td>
</tr>
<tr>
<td>------</td>
<td>-------------------------------------------</td>
<td>---------------------</td>
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<td>SK</td>
<td>Senior software engineer</td>
<td>Interview; Skype meeting;</td>
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<td>SQ</td>
<td>HFT manager</td>
<td>Interview; face to face meeting;</td>
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<tr>
<td>TF</td>
<td>CEO of an HFT firm</td>
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<td>HFT software engineer</td>
<td>Interview; Skype meeting;</td>
</tr>
<tr>
<td>VR</td>
<td>HFT trader and programmer</td>
<td>Interview; face to face meeting;</td>
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<td>VW</td>
<td>HFT trader and code writer</td>
<td>Interview; face to face meeting;</td>
</tr>
<tr>
<td>VX</td>
<td>HFT quantitative analyst</td>
<td>Interview; face to face meeting;</td>
</tr>
<tr>
<td>XM</td>
<td>Senior software developer</td>
<td>Interview; face to face meeting;</td>
</tr>
<tr>
<td>YR</td>
<td>Senior HFT software expert</td>
<td>Interview; Skype meeting;</td>
</tr>
<tr>
<td>YZ</td>
<td>HFT software developer</td>
<td>Interview; Phone conversation;</td>
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References


