Ostfalia
Hochschule für angewandte Wissenschaften

Wolfsburg
Fakultät Wirtschaft

WWP

Wolfsburg Working Papers

No. 22-01

Algorithm Aversion as an Obstacle in the Establishment of Robo Advisors

Ibrahim Filiz, Jan René Judek, Marco Lorenz and Markus Spiwoks, July 2022

Algorithm Aversion as an Obstacle in the Establishment of Robo Advisors

Ibrahim Filiz, Jan René Judek, Marco Lorenz and Markus Spiwoks

Keywords: Algorithm aversion, robo advisors, decisions for others, portfolio choice, diversification, behavioral finance, experiments.

JEL classification: D81, D84, D91, G11, G21, G41, O31, O33

Abstract: Within the framework of a laboratory experiment, we examine to what extent algorithm aversion acts as an obstacle in the establishment of robo advisors. The subjects have to complete diversification tasks. They can either do this themselves or they can delegate them to a robo advisor. The robo advisor evaluates all the relevant data and always makes the decision which leads to the highest expected value for the subject's payment. Although the high level of efficiency of the robo advisor is clear to see, the subjects only entrust their decisions to the robo advisor in around 40% of cases. In this way they reduce their success and their payment. Many subjects orientate themselves towards the 1/n-heuristic, which also contributes to their sub-optimal decisions. As long as the subjects have to make decisions for others, they noticeably make a greater effort and are also more successful than when they make decisions for themselves. However, this does not have an effect on their acceptance of robo advisors. Even when they make decisions on behalf of others, the robo advisor is only consulted in around 40% of cases. This tendency towards algorithm aversion among subjects is an obstacle to the broader establishment of robo advisors.

Ibrahim Filiz, Ostfalia University of Applied Sciences, Faculty of Business, Siegfried-Ehlers-Str. 1, D-38440 Wolfsburg, Germany, Tel.: +49 160 3344 078, E-Mail: ibrahim.filiz@ostfalia.de

Jan René Judek, Ostfalia University of Applied Sciences, Faculty of Business, Siegfried-Ehlers-Str. 1, D-38440 Wolfsburg, Germany, Tel.: +49 5361 892 225 420, E-Mail: ja.judek@ostfalia.de

Marco Lorenz, Georg August University Göttingen, Faculty of Economic Sciences, Platz der Göttinger Sieben 3, D-37073 Göttingen, Germany, Tel.: +49 1522 6672 503, E-Mail: marco.lorenz@stud.uni-goettingen.de

Markus Spiwoks, Ostfalia University of Applied Sciences, Faculty of Business, Siegfried-Ehlers-Str. 1, D-38440 Wolfsburg, Germany, Tel.: +49 5361 892 225 100, E-Mail: m.spiwoks@ostfalia.de

1. Introduction

The traditional portfolio management business is demanding in terms of human resources and therefore comparatively expensive. Wealthy private customers have, however, become more price sensitive since the establishment of low-cost investment opportunities such as exchange-traded funds (ETFs) in recent decades. Many banks are thus trying to find low-cost alternatives, particularly for the support of customers with smaller and medium-sized assets. The increased use of automated processes in portfolio management offers considerable scope for cost reduction. Many banks thus offer robo advisors (see, for example Rühr et al., 2019; Jung et al., 2018; Singh & Kaur, 2017). Robo advisors are algorithms which are specialised in making investment decisions for customers and processing them. However, many customers have reservations about interacting with automated processes (robo advisors), although the latter are often remarkably effective (see, for example, Rossi & Utkus, 2020; Bhatia, Chandani & Chhateja, 2020; D'Acunto, Prabhala & Rossi, 2019; Beketov, Lehmann & Wittke, 2018; Uhl & Rohner, 2018). So-called algorithm aversion is thus a significant problem for the banking sector.

Algorithm aversion particularly occurs when algorithms have to deal with stochastic processes. This is undoubtedly the case with robo advisors. Even when the algorithm makes very good investment decisions, it will – given the stochastic nature of financial market trends – never be able to always make perfect investment decisions. Dietvorst, Simmons & Massey (2015) show that the tolerance of occasional errors by algorithms is much lower than the tolerance shown regarding occasional poor decisions which one has taken oneself or are made by an expert. We speak of algorithm aversion when subjects decline the use of an algorithm even though it is clearly recognisable that their own decisions or those of experts are by no means more successful (for the usual definitions see, for example, Filiz et al., 2021b).

The efficiency of robo advisors is due – among other things – to the fact that they can make meaningful diversification decisions effortlessly. By contrast, investors often find it difficult to determine the expected earnings and the risk (variance) of alternative investments and to take into account the correlations of different investment opportunities in an appropriate way (Ungeheuer & Weber, 2021; Cornil, Hardisty & Bart, 2019; Enke & Zimmermann, 2019; Gubaydullina & Spiwoks, 2015; Eyster & Weizsäcker, 2011; Kallir & Sonsino, 2009; Hedesstrom, Svedsater & Garling, 2006). This is why in practice many portfolios prove to be under-diversified or diversified in an unsuitable way (see, for example Gomes, Haliassos & Ramadorai, 2021; Chu et al., 2017; Dimmock et al., 2016; Anderson, 2013; Hibbert, Lawrence & Prakash, 2012; Goetzmann & Kumar, 2008; Meulbroek, 2005; Polkovnichenko, 2005; Huberman & Sengmueller, 2004; Agnew, Balduzzi & Sundén, 2003; Guiso, Haliassos & Japelli, 2002; Benartzi, 2001; Benartzi & Thaler, 2001; Barber & Odean, 2000; Bode, van Echelpoel & Sievi, 1994; Blume & Friend, 1975; Lease, Lewellen & Schlarbaum, 1974).

We carry out an economic experiment in which the subjects have to make four investment decisions. They can choose between different investment alternatives in each of the four cases. They are informed of the possible returns, the probability that these returns will materialise, and the correlations of the different investment opportunities. The subjects can either make their own diversification decisions or entrust the task to a robo advisor. The subjects know that the robo advisor takes all of the relevant data into account (expected value of the returns, the probability that the returns will materialise, the correlation coefficients of the return development of the different investments), evaluates it optimally and takes it into account in its investment decisions. However, the subjects are also aware of the fact that the robo advisor cannot know which random event will occur next. The subjects receive the risk-adjusted return of their investment decisions as payment. We examine whether algorithm aversion occurs in this context, and whether this can lead to a reduction of the risk-adjusted returns.

In the meantime, there is a considerable amount of research results available on measures which can mitigate algorithm aversion (see, for example, Hinsen et al., 2022; Filiz et al., 2021a; Gubaydullina et al., 2021; Kim, Giroux & Lee, 2021; Jung & Seiter, 2021; Castelo, Bos & Lehmann, 2019; Dietvorst, Simmons & Massey, 2018; Taylor, 2017). However, it has not yet been considered whether algorithm aversion is less pronounced when a subject has to make decisions for other persons.

Some empirical research findings indicate that when making decisions for others a change in the willingness of subjects to take risks can come into play (see, for example Andersson et al., 2022; Eriksen, Kvaløy & Luzuriaga, 2020; Vieider et al., 2016; Pahlke, Strasser & Vieider, 2015; Füllbrunn & Luhan, 2015; Bolton, Ockenfels & Stauf, 2015; Pahlke, Strasser & Vieider, 2012; Chakravarty et al., 2011; Charness & Jackson, 2009; Reynolds, Joseph & Sherwood, 2009). This is particularly true when the person for whom a decision is being made is actually present (Polman, 2012). Later on, the persons for whom a decision is made may demand that the decision-maker justify their choices. If this is known in advance, it can lead to particular care on the part of the decision-maker. If the decision is delegated to an algorithm, however, the decision-makers do not have to justify their choices. This could possibly contribute towards a reduction of algorithm aversion. This study examines whether this is actually the case.

2. Experimental design

The subjects have the task of creating a portfolio of shares. However, the subjects do not profit from gains in the share prices – they only profit (once) from the dividend payments of the shares in 2022. They receive information about the possible amount of the dividends and the respective probabilities of the different amounts. In addition, they can see how the dividends of the shares have developed over the last ten years.

The first task is illustrated here. There are two shares to choose from: share Y and share Z. The dividend payments of both companies are independent random processes with two possible configurations: 8 Experimental Currency Units (ECU) and ECU 0. The probability of each of these occurring is 50%. The expected values of the dividend payments are thus ECU 4 each. The dividend payments of the two shares are wholly uncorrelated (correlation coefficient = 0). Table 1 shows the level of the dividend payments of the two shares in the past ten years.

Table 1: History of the random events of the dividend payments in task 1

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Share Y	ECU 8	ECU 0	ECU 8	ECU 8	ECU 8	ECU 0	ECU 8	ECU 0	ECU 0	ECU 0	?
Share Z	ECU 0	ECU 0	ECU 8	ECU 0	ECU 8	ECU 8	ECU 0	ECU 0	ECU 8	ECU 8	?

The subjects are allowed to compile a portfolio consisting of two shares. They can thus choose two Y shares, two Z shares, or one Y share and one Z share. As payment they receive the risk-adjusted dividends for 2022. A risk-adjusted dividend is equivalent to the dividend payment divided by the variance of the dividend payments of the chosen portfolio. The task thus consists of achieving the highest possible dividends with the lowest possible risk (low variance). The total of all risk-adjusted dividends (in ECU) which are obtained via portfolio decisions is multiplied by five at the end and then paid in euros.

As the subjects do not know the next random events for the dividend payments of share Y and share Z, it makes sense for them to orientate themselves towards the expected values and the variances of the three possible portfolios.

Table 2: Expected values and variances in task 1

Possible portfolios	Expected value of the dividend	Variance	Expected value of the payment
2 Y shares	ECU 8	64	ECU 0.125 or € 0.625
2 Z shares	ECU 8	64	ECU 0.125 or € 0.625
1 Y share + 1 Z share	ECU 8	32	ECU 0.25 or € 1.25

Rational economic subjects orientate themselves towards the expected values of the payment, i.e., they select the mixed securities portfolio (1 Y share + 1 Z share). This is exactly how the robo advisor works.

All of the subjects have been familiarised with stochastic processes and the calculation of probabilities at school and also at the beginning of their degree programmes. They are aware of the fact that one cannot draw any conclusions about future random occurrences from an independent random event. Nevertheless, the temptation is great to make a forecast on which events will occur in the cases of the two shares in 2022 which is derived from the sequence of favourable and unfavourable dividend payments. People tend to see patterns even where there are definitely none (see, for example Zielonka, 2004; Wärneryd, 2001; Gilovich, Vallone & Tversky, 1985; Roberts, 1959). Subjects who have succumbed to the hot hand fallacy (Burns, 2001; Gilovich, Vallone & Tversky, 1985) will tend to choose the portfolio of 2 Z shares. Subjects who believe in the gambler's fallacy (Rogers, 1998; Tversky & Kahneman, 1971) will prefer the 2 Y shares portfolio. Subjects who think they can predict the next random events will not make use of the robo advisor. Subjects who want to maximise the expected value of their payment can, however, sleep easily if they delegate the decision to the robo advisor, because the robo advisor is specialised in making meaningful portfolio decisions and takes all of the relevant information into account in an optimal way in order to achieve risk-adjusted dividend payments which are as high as possible. The subjects are informed of this.

The second task is somewhat more complex. Once again, there are two shares to choose from (share X and share Q). Both of the shares can pay a dividend of either ECU 4 or ECU 0. The probability of each of these occurring is 50%. The expected values of the dividend payments are thus ECU 2 each. Once again, they are independent random events. The dividend payments of share X and share Q are completely uncorrelated (correlation coefficient = 0).

Table 3 shows the level of the dividend payments of the two shares in the last 10 years.

Table 3: History of the random events of the dividend payments in task 2

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Share X	ECU 0	ECU 0	ECU 4	ECU 0	ECU 0	ECU 0	ECU 4	ECU 4	ECU 4	ECU 4	?
Share Q	ECU 0	ECU 4	ECU 4	ECU 4	ECU 0	ECU 4	ECU 0	ECU 0	ECU 4	ECU 0	?

The subjects can compile a portfolio consisting of four shares. They can thus choose either four X shares, or four Q shares, or three X shares and one Q share, or three Q shares and one X share, or two X shares and two Q shares. Neither the subjects nor the robo advisor know what the random events (dividend payments for share X and share Q) will be in 2022. A rational subject would orientate themselves towards the expected value of the payment and select the portfolio 2 X shares + 2 Q shares (see Table 4). This is exactly what the robo advisor does.

Table 4: Expected values and variances in task 2

Possible portfolios	Expected value of the dividend	Variance	Expected value of the payment
4 X shares	ECU 8	64	ECU 0.125 or € 0.625
4 Q shares	ECU 8	64	ECU 0.125 or € 0.625
3 X shares + 1 Q share	ECU 8	40	ECU 0.20 or € 1
3 Q shares + 1 X share	ECU 8	40	ECU 0.20 or € 1
2 X shares + 2 Q shares	ECU 8	32	ECU 0.25 or € 1.25

The third task and the fourth task can no longer be accomplished with a crude diversification strategy such as the 1/n heuristic (e.g., Fernandes, 2013; Baltussen & Post, 2011) because these are companies which belong to the same industry sector and whose dividend payments depend on the success of the sector. The dividend payments of the two shares are thus completely positively correlated (correlation coefficient = 1). Table 5 shows the amount of the dividend payments in the past ten years.

Table 5: History of the random events of the dividend payments in task 4

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Share M	ECU 4	ECU 0	ECU 4	ECU 0	ECU 0	ECU 0	ECU 4	ECU 4	ECU 0	ECU 4	?
Share P	ECU 3	ECU 1	ECU 3	ECU 1	ECU 1	ECU 1	ECU 3	ECU 3	ECU 1	ECU 3	?

A phase in which companies in this sector are either successful or are struggling occurs purely coincidentally with a probability of 50%. Previous events thus provide no indication of which random evens might occur in the future. The expected value of the dividend payments is thus ECU 2 for both shares. The subjects can compile a portfolio consisting of four shares.

Given that the dividend payments for both shares are 100% positively correlated, a mixture of the two shares does not create any diversification effect. The optimal strategy is to select four P shares, because that is the minimum variance portfolio (see Table 6). This is precisely the strategy pursued by the robo advisor.

Table 6: Expected values and variances in task 4

Possible portfolios	Expected value of the dividend	Variance	Expected value of the payment
4 M shares	ECU 8	64	ECU 0.125 or € 0.625
4 P shares	ECU 8	16	ECU 0.50 or € 2.50
3 M shares + 1 P share	ECU 8	49	ECU 0.165 or € 0.825
3 P-shares + 1 M share	ECU 8	25	ECU 0.32 or € 1.60
2 M shares + 2 P shares	ECU 8	36	ECU 0.225 or € 1.125

The experiment proceeds as follows: First, the subjects read the instructions and answer the control questions (see Appendices 1 and 2). Afterwards, they make the four portfolio decisions of tasks 1 to 4 either with the help of the robo advisor or independently. For each of the four tasks, the subjects can decide again whether they want to delegate the task to the robo advisor or whether they want to choose a portfolio composition themselves. Only after the four tasks have been completed is it revealed which random events have occurred in this session and to which compensation the subjects have progressed. The payment is then made in cash.

In the treatment entitled 'Self' the subjects receive the payment themselves. In the treatment entitled 'Representative' another participant in the session receives the payment which has been obtained. In the treatment 'Representative', after the payment has been made the subjects are informed about who is responsible for which payment.

Figure 1: The treatment 'Self' and the treatment 'Representative'

Treatment Self:	**Treatment Representative:**
The subjects select the portfolio and profit themselves from the success of their decisions.	The subjects select the portfolio, but another subject in the session profits from the success of the decisions.

Let us assume, for example, that subject B receives the payment achieved by subject A and vice-versa. After the experiment, subject A could demand in a personal conversation that subject B justifies his or her decisions. And subject B could also demand that subject A justifies their decisions. All of the subjects who participate in the treatment 'Representative' are informed about this at the beginning of the experiment.

3. Hypotheses

The most meaningful strategy is to delegate all four tasks to the robo advisor. The robo advisor always makes the most meaningful decisions. It always selects the portfolio composition which maximises the expected value of the payment in €. It would actually be possible to work out this optimal decision oneself. However, the amount of effort required to do so is considerable. The subjects can make mistakes when calculating the expected payment amount. The robo advisor, on the other hand, always evaluates all of the relevant data in an optimal way and always makes the decision which maximises the expected value of the payment. Nevertheless, it has to be expected that some subjects will have reservations about using a robo advisor. The wide variety of previous findings on the occurrence of algorithm aversion make this highly likely (Mahmud et al., 2022; Kawaguchi, 2021; Burton, Stein & Jensen, 2020; Castelo, Bos & Lehmann, 2019, Prahl & Van Swol, 2017).

Hypothesis 1 is therefore: Not all of the subjects will trust the robo advisor (algorithm), although it is not possible for them to make a better decision. This means that algorithm aversion will occur.

Null hypothesis 1 is: All of the subjects will trust the robo advisor (algorithm). This means that algorithm aversion will not occur.

If the subjects are wary of using the robo advisor (algorithm aversion), this may well lead – on average – to a reduction of the payment they obtain. Algorithm aversion will presumably cause a loss of potential earnings.

Hypothesis 2 is therefore: The more frequently the subjects delegate their decision to the robo advisor, the higher their payments will be.

Null hypothesis 2: The frequency with which the subjects delegate their decisions to the robo advisor does not have a positive influence on their payment.

Among the subjects there will presumably be some who pursue a crude diversification strategy (1/n-heuristic; see, for example Fernandes, 2013; Morrin et al., 2012; Baltussen & Post, 2011; Huberman & Jiang, 2006; Benartzi & Thaler, 2001). This strategy can lead to success in tasks 1 and 2. In tasks 3 and 4, on the other hand, it cannot lead to success. For an optimal solution of tasks 3 and 4, it is necessary to also take into account the correlation coefficients alongside the expected values of the dividends.

Hypothesis 3 is: Subjects who do not deploy the algorithm partly neglect the correlations, and in the case of tasks 3 and 4 they find the optimal solution significantly less often than in tasks 1 and 2.

Null hypothesis 3: Subjects who do not deploy the algorithm do not neglect the correlations, and in the case of tasks 3 and 4 they do not find the optimal solution significantly less often than in tasks 1 and 2.

On the basis of the existing research on proxy decision-making (see, for example Pahlke, Strasser & Vieider, 2015; Polman, 2012; Pahlke, Strasser & Vieider, 2012; Charness & Jackson, 2009; Reynolds, Joseph & Sherwood, 2009) we presume that the subjects who make decisions for others (the treatment 'Representative'), consider their decisions more carefully and try harder to make meaningful decisions. After all, the persons for whom the decisions are being made are actually present. At the end of the experiment, who decided for whom and what the results were is announced. All of the subjects in the treatment 'Representative' are aware of this. In other words, they have to expect that they will need to justify their decisions. The subjects in the treatment 'Self', on the other hand, are only responsible for themselves. They need not fear that someone will demand that they justify their decisions. We therefore presume that algorithm aversion will occur less frequently in the treatment 'Representative' than in the treatment 'Self'. In addition, we presume that those persons in the treatment 'Representative' who do not want to trust the robo advisor – for whatever reason – will make a greater effort to select meaningfully diversified portfolios.

Hypothesis 4 is therefore: The solution of the tasks is delegated to the robo advisor significantly more often in the treatment 'Representative' than in the treatment 'Self'.

Null hypothesis 4: The solution of the tasks is not delegated to the robo advisor significantly more often in the treatment 'Representative' than in the treatment 'Self'.

Hypothesis 5 is thus: Those persons who do not want to trust the robo advisor will choose the optimal portfolio structure significantly more often in the treatment 'Representative' than in the treatment 'Self'.

Null hypothesis 5: Those persons who do not want to trust the robo advisor will not choose the optimal portfolio structure significantly more often in the treatment 'Representative' than in the treatment 'Self'.

4. Results

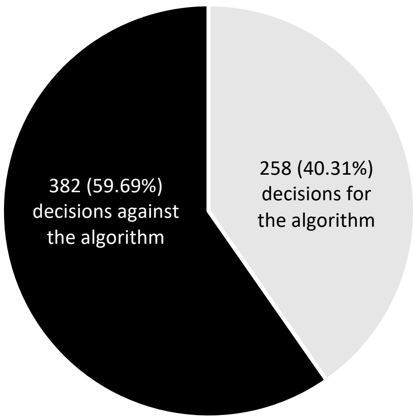
This economic experiment was carried out between 20-28 April 2022 in the Ostfalia Laboratory of Experimental Economic Research (OLEW) at Ostfalia University of Applied Sciences in Wolfsburg. A total of 160 students of the Ostfalia University of Applied Sciences took part in the experiment. Of these, 112 subjects (70%) were male and 48 subjects (30%) were female. Of the 160 participants, 98 subjects (61.25%) study at the Faculty of Economics and Business, 38 subjects (23.75%) at the Faculty of Vehicle Technology, and 24 subjects (15%) at other faculties. Their average age is 23.6 years.

Of the 160 participants, 80 subjects played the treatment 'Self' and 80 played the treatment 'Representative'. The experiment was carried out using z-Tree (Fischbacher, 2007). The time needed for reading the instructions of the experiment (Appendix 1), answering the test questions (Appendix 2) and carrying out the four tasks is 15 minutes on average. An average payment of € 6.89 seems very attractive for the amount of time required. It is intended to be sufficient incentive for meaningful economic decisions, and the subjects did actually give the impression of being concentrated and motivated.

In the first instance, it can be seen that algorithm aversion occurs to a considerable extent. Although it is clear to all of the participants that using the algorithm (robo advisor) definitely leads to the best possible decisions, the robo advisor is deployed in less than half of the cases. 160 subjects have to make four decisions each. This is a total of 640 decisions. The subjects decide to delegate the task to the robo advisor in only 258 cases (40.31%). In 382 cases (59.69%), the subjects refrain from using the algorithm (Figure 2). The reason why this is so remarkable is that all of the subjects knew that the robo advisor evaluates all of the relevant data in an optimal way and therefore always makes the best possible decision.

An average subject relies on the algorithm in only 1.612 out of 4 rounds. The t-test shows in all clarity that null hypothesis 1 has to be rejected (p-value = 0.000). The Z-test supports that only very few subjects (36 out of 160) consistently follow the rational strategy and rely on the algorithm in all rounds of the experiment (p-value = 0.000). Algorithm aversion thus obviously occurs to a considerable extent (59.69% of all decisions).

Figure 2: Decisions for and against the algorithm (robo advisor)



It is of particular interest whether this tendency towards algorithm aversion really leads to a smaller number of optimal diversification decisions and whether the payments are lower than would have been the case when the subjects had consistently trusted the robo advisor. After all, one cannot simply presume that the decisions of the subjects who do not always use the robo advisor are really less successful.

Table 7: Average success in relation to the extent of algorithm aversion

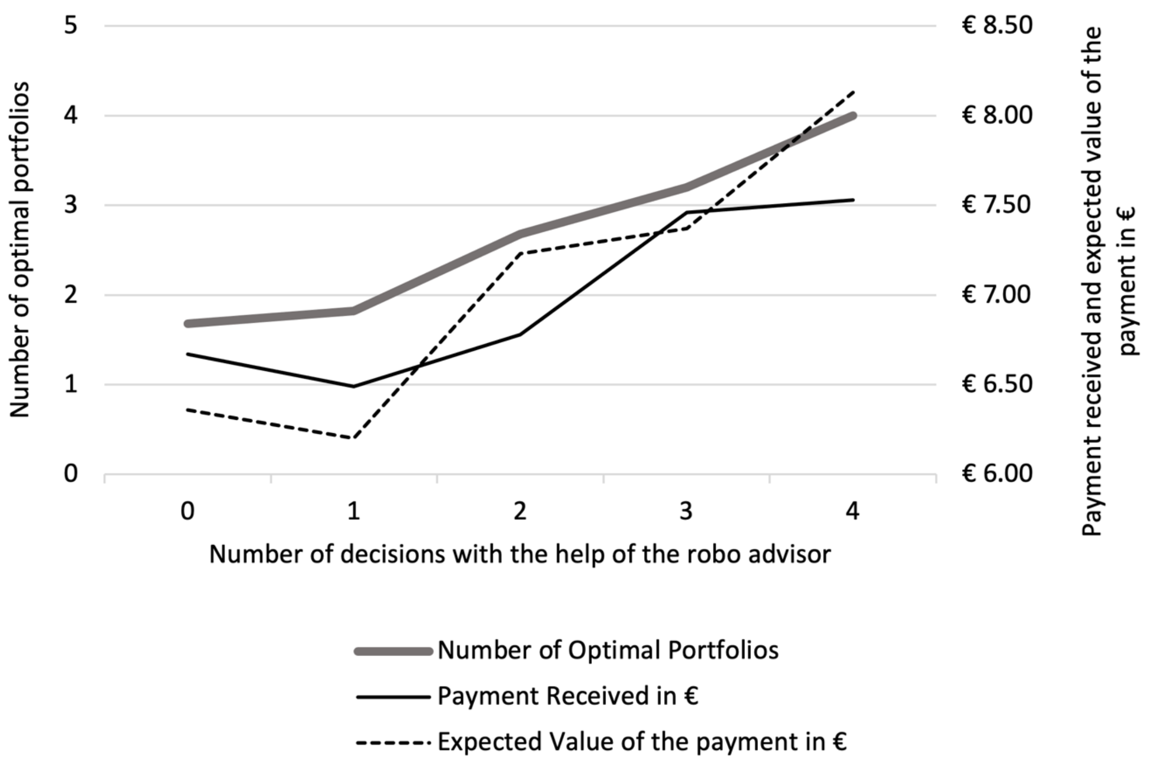
Number of times the algorithm was chosen	Number of subjects	Optimal portfolios	Expected value of the payment in €	Actual payment in €
0	53	89 (41.98%)	€ 6.36	€ 6.67
1	39	71 (45.51%)	€ 6.20	€ 6.49
2	19	51 (67.11%)	€ 7.23	€ 6.78
3	15	48 (80.00%)	€ 7.37	€ 7.46
4	34	136 (100%)	€ 8.13	€ 7.53

53 subjects did not delegate their decision to the robo advisor a single time. In 89 out of 212 decisions (41.98%), these subjects selected optimal portfolios. On average they achieved an expected payment value of € 6.36. How much the actual payment is also depends on the specific random events (dividend payments). Here there was an average payment of € 6.67 (Table 7).

34 subjects delegated all four of their decisions to the robo advisor. As was to be expected, in 136 out of 136 decisions (100%), the optimal portfolios were chosen. The subjects achieved an expected payment value of € 8.13. The specific random events (dividend payments) led to an average payment of € 7.53 (Table 7).

Figure 3 shows clearly that the more frequently the subjects delegate their decision to the robo advisor, the more successful they are. The subjects who do not put their faith in the robo advisor a single time achieve an average of only 1.68 optimal portfolios The subjects who use the robo advisor to solve all four tasks make 4.00 optimal decisions. The F-test confirms: the more frequently the robo advisor is used, the more optimal portfolios are compiled (thick grey line, left scale, p-value = 0.000) and the higher the expected value of the payment (dashed black line, right scale, p-value = 0.000), and the higher the actual payment (continuous black line, right scale, p-value = 0.000).

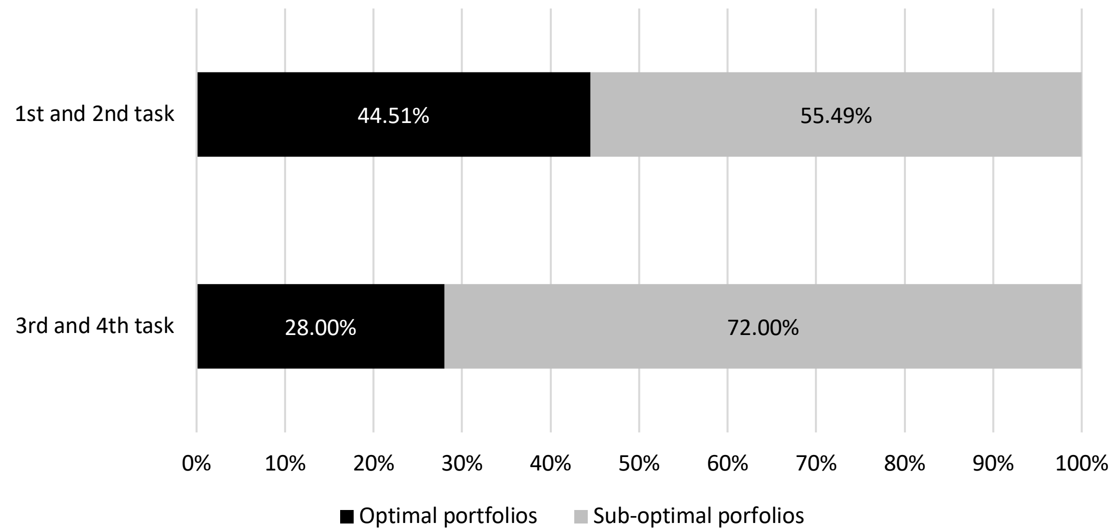
Figure 3: Average success in relation to the extent of algorithm aversion



The stronger the effect of algorithm aversion, the less successful the subjects are. Null hypothesis 2 thus has to be discarded.

Now let us look at the success of the decisions which are not delegated to the robo advisor. Tasks 1 and 2 can be solved well with the simple understanding of diversification of the 1/n heuristic. In tasks 3 and 4, however, it is absolutely necessary to take the correlations between the dividend payments of the two shares into account and to understand the variances of the dividend payments of the two shares. Among the decisions which are not delegated to the robo advisor, a clear difference can indeed be seen between the success rate in tasks 1 and 2 on the one hand and the success rates in tasks 3 and 4 on the other. In tasks 1 and 2, 81 out of 182 decisions (44.51%) lead to optimal portfolios. In tasks 3 and 4, on the other hand, only 56 out of 200 decisions (28%) lead to optimal portfolios which maximise the expected value of the payment. In the chi square test, this difference proves to be significant (p-value = 0.001.) Null hypothesis 3 thus has to be rejected (Figure 4).

Figure 4: Percentage share of optimal portfolios according to tasks

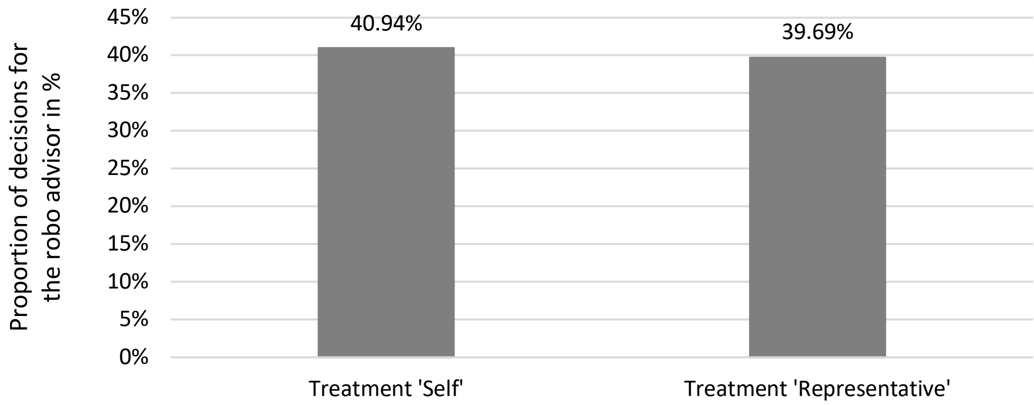


In a comparison of the two treatments ‘Self’ and ‘Representative’, no noteworthy differences with regard to use of the robo advisor can be seen. In the treatment ‘Self’, 131 of out 320 decisions (40.94%) are delegated to the robo advisor. In the treatment ‘Representative’, 127 out of 320 decisions (39.69%) are delegated to the robo advisor (Table 8, Figure 5). This is only a very small difference. It proves to be insignificant both in the Wilcoxon rank sum test (p-value = 0.7524) as well as in the chi square test (p-value = 0.7470). Null hypothesis 4 can therefore not be rejected.

Table 8: Influence of the treatments on algorithm aversion

Treatment	Robo advisor	Own decision	Total
Self	131	189	320
Representative	127	193	320

Figure 5: Acceptance of the robo advisor according to treatments



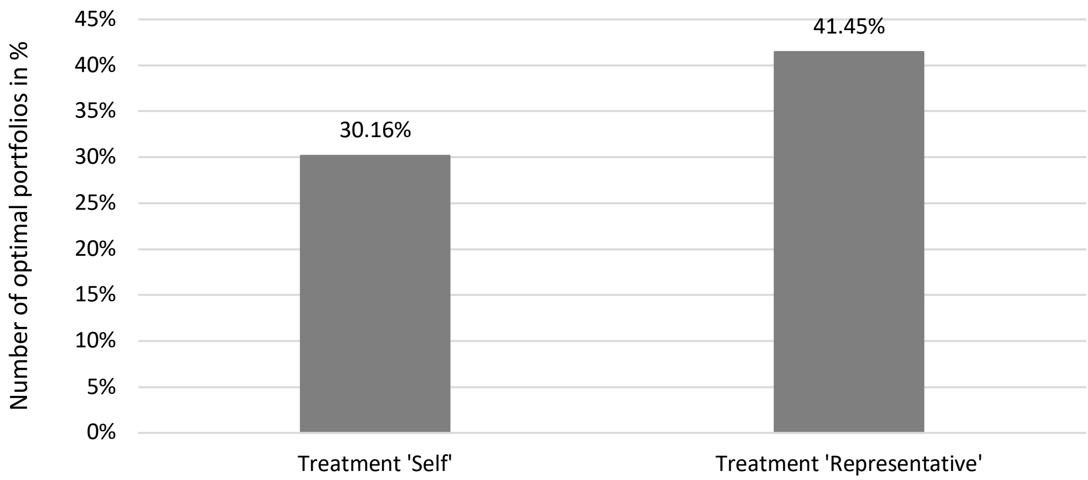
This is a surprising result. The subjects in the treatment 'Representative' could have easily transferred their responsibility for the payment of another person to the robo advisor. Given that the robo advisor is known for the fact that it always makes optimal decisions, nobody needs to be afraid of being criticised. However, a large part of the subjects obviously have such far-reaching reservations regarding the deployment of a robo advisor that they do not want to take this route. We thus have to come to the conclusion that algorithm aversion occurs frequently and is by no means easy to overcome.

However, it is noticeable that it does make a difference whether one makes decisions for oneself or for others. The subjects in the treatment 'Representative' really do make a greater effort to take meaningful decisions. This can be seen in the decisions they take without using the robo advisor. In 57 out of 189 decisions (30.16%) the subjects in the treatment 'Self' succeed in building optimal portfolios (portfolios with the highest expectation value for the payment in €). In 80 out of 193 decisions (41.45%), the subjects in the treatment 'Representative' succeed in building optimal portfolios (portfolios with the highest expectation value for the payment in €) (Table 9, Figure 6). This difference turns out to be statistically significant in the chi square test (p-value = 0.021).

Table 9: Success of portfolio decisions without the robo advisor according to treatments

Treatment	Number of subjects	Number of optimal portfolios without the robo advisor	Number of sub-optimal portfolios without the robo advisor	Number of decisions made by the robo advisor	Total
Self	80	57	132	131	320
Representative	80	80	113	127	320

Figure 6: Success of the portfolio decisions without the robo advisor according to treatments



A clear difference between the two treatments can definitely be seen. The subjects behave differently depending on whether they are deciding for themselves or for others. They obviously act less impulsively in the treatment 'Representative', and weigh up more precisely which portfolio composition will presumably lead to the largest payment. However, this effort to make meaningful decisions does not lead to a greater acceptance of robo advisors. The subjects' reservations about using an algorithm are obviously stronger than their wish to make decisions for others with particular care.

5. Conclusion

Robo advisors are algorithms which can automatically make investment decisions for asset management customers. Given the increased price sensitivity of wealthy private clients, robo advisors are one way to offer solid portfolio management decisions at a low cost. However, customers have considerable reservations about algorithms, even when they are very efficient systems. This phenomenon, which is known as algorithm aversion, is considered in more detail in this study.

In a laboratory experiment, subjects make a total of four portfolio decisions. They can either try to determine the optimal portfolio composition in each case themselves, or they can delegate the task to a robo advisor. The robo advisor takes all the relevant information into account in an optimal way and always chooses the portfolio composition which leads to the highest expected value of the payment in €. The subjects are familiar with the qualities of the robo advisor. Nevertheless, they only use it in around 40% of all cases. In around 60% of all decision-making situations, the subjects trust in their own judgement, although it must be clear to them that they are not able to make better decisions than the robo advisor. Algorithm aversion thus occurs to a great extent.

The actual success rate of the subjects who do not put their faith in the robo advisor is indeed lower than that of the robo advisor. This applies to the average number of optimal portfolio compositions, to the average expected values of their payment in €, and also with regard to the actually obtained payment in €. It is crystal clear that the more frequently the subjects delegate their decisions to the robo advisor, the greater their success. With their aversion towards the algorithm, the subjects are recognisably damaging themselves.

The subjects have particular difficulties when trying to take into account the correlation between the different investments. Tasks which can be solved with the simple diversification strategy of the 1/n heuristic (tasks 1 and 2) are dealt with successfully significantly more often than tasks which cannot be suitably dealt with using the 1/n heuristic (tasks 3 and 4).

Ultimately it becomes clear that subjects who have to make decisions for others approach the task in a more careful and concentrated way. Among the decisions which are not made by the robo advisor, there are significantly more optimal portfolios within the subjects who make decisions for others than among those who decide for themselves. However, this does not have an effect on algorithm aversion. Regardless of whether the subjects decide for themselves or for others, a readiness to delegate the decision to the robo advisor can only be seen in around 40% of decisions.

To summarise, the following can be stated: The deployment of robo advisors can, under certain circumstances, be a low-cost and very efficient alternative to traditional asset management. However, algorithm aversion hinders the establishment of the business which could be had with robo advisors.

References

Agnew, J., Balduzzi, P. & Sundén, A. (2003), Portfolio Choice and Trading in a Large 401(k) Plan, *The American Economic Review*, 93(1), 193-215.

Anderson, A. (2013), Trading and Under-Diversification, *Review of Finance*, 17(5), 1699–1741.

Andersson, O., Holm, H. J. & Tyran, J.-R. & Wengström, E. R. (2022), Deciding for Others Reduces Loss Aversion, *Management Science*, 62(1), 29-36.

Baltussen, G. & Post, G. T. (2011), Irrational Diversification: an Examination of Individual Portfolio Choice, *Journal of Financial and Quantitative Analysis*, 46(5), 1463-1491.

Barber, B. M. &, Odean, T. (2000), Trading is Hazardous to your Wealth: The Common Stock Investment Performance of Individual Investors, *Journal of Finance*, 55(2), 773-806.

Beketov, M., Lehmann, K. & Wittke, M. (2018), Robo Advisors: quantitative methods inside the robots, *Journal of Asset Management*, 19, 363–370.

Benartzi, S. (2001), Excessive Extrapolation and the Allocation of 401(k) Accounts to Company Stock, *The Journal of Finance*, 56(5), 1747-1764.

Benartzi, S. & Thaler, R. H. (2001), Naïve Diversification Strategies in Defined Contribution Saving Plans, *American Economic Review*, 91(1), 79-98.

Bhatia, A., Chandani, A. & Chhateja, J. (2020), Robo advisory and its potential in addressing the behavioral biases of investors — A qualitative study in Indian context, *Journal of Behavioral and Experimental Finance*, 25.

Blume, M. E. & Friend, I. (1975), The Asset Structure of Individual Portfolios and Some Implications for Utility Functions, *The Journal of Finance*, 30(2), 585-603.

Bode, M., van Echelpoel, A. & Sievi, C. R. (1994), Multinationale Diversifikation: Viel zitiert, kaum befolgt, *Die Bank*, 94(4), 202-206.

Bolton, G. E., Ockenfels, A. & Stauf, J. (2015), Social responsibility promotes conservative risk behavior, *European Economic Review*, 74(C), 109-127.

Burton, J., Stein, M. & Jensen, T. (2020), A systematic review of algorithm aversion in augmented decision making, *Journal of Behavioral Decision Making*, 33(2), 220-239.

Burns, B. D. (2001), The hot hand in basketball: Fallacy or adaptive thinking, *Proceedings of the Annual Meeting of the Cognitive Science Society*, 23(23), 152-157.

Castelo, N., Bos, M. W. & Lehmann, D. R. (2019), Task-dependent algorithm aversion, *Journal of Marketing Research*, 56(5), 809-825.

Chakravarty, S., Harrison, G. W., Haruvy, E., Rutstrom, E. (2011), Are You Risk Averse over Other People's Money?, *Southern Economic Journal*, 77(4), 901-913.

Charness, G. & Jackson, M. O. (2009), The role of responsibility in strategic risk-taking, *Journal of Economic Behavior & Organization*, 69(3), 241–247.

Chu, Z., Wang, Z., Xiao, J. J., & Zhang, W. (2017), Financial literacy, portfolio choice and financial well-being, *Social Indicators Research*, 132(2), 799-820.

Cornil, Y., Hardisty, D. J., & Bart, Y. (2019), Easy, breezy, risky: Lay investors fail to diversify because correlated assets feel more fluent and less risky, *Organizational Behavior and Human Decision Processes*, 153, 103-117.

D'Acunto, F., Prabhala, N. & Rossi, A. G. (2019), The Promises and Pitfalls of Robo-Advising, *The Review of Financial Studies*, 32(5), 1983–2020.

Dietvorst, B. J., Simmons, J. P. & Massey, C. (2018), Overcoming algorithm aversion: People will use imperfect algorithms if they can (even slightly) modify them, *Management Science*, 64(3), 1155-1170.

Dietvorst, B. J., Simmons, J. P. & Massey, C. (2015), Algorithm aversion: People erroneously avoid algorithms after seeing them err, *Journal of Experimental Psychology: General*, 144(1), 114-126.

Dimmock, S. G., Kouwenberg, R., Mitchell, O. S. & Peijnenburg, K. (2016), Ambiguity Aversion and Household Portfolio Choice Puzzles: Empirical Evidence, *Journal of Financial Economics*, 119, 559-577.

Enke, B., & Zimmermann, F. (2019), Correlation neglect in belief formation, *The Review of Economic Studies*, 86(1), 313-332.

Eriksen, K. W., Kvaløy, O. & Luzuriaga, M. (2020), Risk-taking on behalf of others, *Journal of Behavioral and Experimental Finance*, 26(C), 1-13.

Eyster, E. & Weizsäcker, G. (2011), Correlation Neglect in Financial Decision Making, DIW Discussion Papers, No. 1104, Berlin.

Fernandes, D. (2013), The 1/N Rule Revisited: Heterogeneity in the Naïve Diversification Bias, *International Journal of Research in Marketing*, 30(3), 310-313.

Filiz, I., Judek, J. R., Lorenz, M. & Spiwoks, M. (2021a), Reducing algorithm aversion through experience, in: *Journal of Behavioral and Experimental Finance*, Bd. 31, 1-8, DOI 10.1016/j.jbef.2021. 100524.

Filiz, I., Judek, J. R., Lorenz, M. & Spiwoks, M. (2021b), The Tragedy of Algorithm Aversion, WWP – Wolfsburg Working Papers, Nr. 21-02, Wolfsburg.

Füllbrunn, S. & Luhan, W. J. (2015), Am I My Peer's Keeper? Social Responsibility in Financial Decision Making, Ruhr Economic Paper, No. 551.

Gilovich, T., Vallone, R. & Tversky, A. (1985), The hot hand in basketball: On the misperception of random sequences, *Cognitive psychology*, 17(3), 295-314.

Goetzmann, W. N. & Kumar, A. (2008), Equity Portfolio Diversification, *Review of Finance*, 12(3), 433-463.

Gomes, F., Haliassos, M., & Ramadorai, T. (2021), Household finance, *Journal of Economic Literature*, *59*(3), 919-1000.

Gubaydullina, Z., Judek, J. R., Lorenz, M. & Spiwoks, M. (2021), Creative Drive and Algorithm Aversion – The Impact of Influence in the Process of Algorithmic Decision-making on Algorithm Aversion, WWP – Wolfsburg Working Papers, Nr. 21-04, Wolfsburg.

Gubaydullina, Z. & Spiwoks, M. (2015), Correlation Neglect, Naïve Diversification, and Irrelevant Information as Stumbling Blocks for Optimal Diversification, *Journal of Finance and Investment Analysis*, 4(2), 1-19.

Guiso, L., Haliassos, M. & Japelli, T. (2002), Household Portfolios, MIT Press, Cambridge, MA.

Hedesstrom, T. M., Svedsater, H. & Garling, T. (2006), Covariation Neglect among Novice Investors, Journal of Experimental Psychology-Applied, 12(3), 155-165.

Hibbert, A. M., Lawrence, E. R. & Prakash, A. J. (2012), Can Diversification Be Learned? *The Journal of Behavioral Finance*, 13(1), 38-50.

Hinsen, S., Hofmann, P., Jöhnk, J. & Urbach, N. (2022), How Can Organizations Design Purposeful Human-AI Interactions: A Practical Perspective From Existing Use Cases and Interviews, Proceedings of the 55th Hawaii International Conference on System Sciences (HICSS), Honolulu, HI, University of Hawai'i at Manoa, Hamilton Library.

Huberman, G. & Sengmueller, P. (2004), Performance and Employer Stock in 401(k) Plans, Review of Finance, 8(3), 403-443.

Huberman, G., & Jiang, W. (2006), Offering versus choice in 401 (k) plans: Equity exposure and number of funds. *The Journal of Finance*, 61(2), 763-801.

Jung, D., Dorner, V., Glaser, F. & Morana, S. (2018), Robo-Advisory - Digitalization and Automation of Financial Advisory, *Business & Information Systems Engineering*, 60(1), 81-86.

Jung, M. & Seiter, M. (2021), Towards a better understanding on mitigating algorithm aversion in forecasting: an experimental study*, Journal of Management Control*, 32, 495-516.

Kallir, I. & Sonsino, D. (2009), The Neglect of Correlation in Allocation Decisions, Southern Economic Journal, 75(4), 1045-1066.

Kawaguchi, K. (2021), When will workers follow an algorithm? A field experiment with a retail business, *Management Science*, 67(3), 1670-1695.

Kim, J., Giroux, M. & Lee, J. C. (2021), When do you trust AI? The effect of number presentation detail on consumer trust and acceptance of AI recommendations, *Psychology & Marketing*, 38(7), 1140-1155.

Lease, R. C., Lewellen, W. G. & Schlarbaum, G. G. (1974), The Individual Investor: Attributes and Attitudes, *The Journal of Finance*, 29(2), 413-433.

Mahmud, H., Islam, A. N., Ahmed, S. I., & Smolander, K. (2022), What influences algorithmic decision-making? A systematic literature review on algorithm aversion, *Technological Forecasting and Social Change*, 175, 121390, 1-26.

Meulbroek, L. (2005), Company Stock in Pension Plans: how costly is it?, *The Journal of Law and Economics*, 48(2), 443-474.

Morrin, M., Inman, J. J., Broniarczyk, S. M., Nenkov, G. Y. & Reuter, J. (2012), Investing for Retirement: The Moderating Effect of Fund Assortment Size on the 1/N Heuristic, *Journal of Marketing Research*, 49(4), 537-550.

Pahlke, J., Strasser, S. & Vieider, F. M. (2015), Responsibility effects in decision making under risk, *Journal of Risk and Uncertainty*, 51(2), 125–146.

Pahlke, J., Strasser, S. & Vieider, F. M. (2012), Risk-taking for others under accountability, E*conomics Letters*, 114(1), 102-105.

Polkovnichenko, V. (2005), Household Portfolio Diversification: a Case for Rank-dependent Preferences, *Review of Financial Studies*, 18, 1467-1502.

Polman, E. (2012), Self–other decision making and loss aversion, *Organizational Behavior and Human Decision Processes*, 119(2), 141–150.

Prahl, A., & Van Swol, L. (2017), Understanding algorithm aversion: When is advice from automation discounted?, *Journal of Forecasting*, 36(6), 691-702.

Reynolds, D. B., Joseph, J. & Sherwood, R. (2009), Risky Shift Versus Cautious Shift: Determining Differences In Risk Taking Between Private And Public Management Decision-Making, *International Journal of Economics and Business Research*, 7(1), 63-78.

Roberts, H. V. (1959), Stock market ‘‘patterns’’ and financial analysis: Methodological suggestions, *Journal of Finance*, 1(14), 1–10.

Rogers, P. (1998), The cognitive psychology of lottery gambling: A theoretical review, *Journal of gambling studies*, 14(2), 111-134.

Rossi, A. G. & Utkus, S. P. (2020), Who Benefits from Robo-advising? Evidence from Machine Learning, SSRN Working Paper, https://ssrn.com/abstract=3552671 or http://dx.doi.org/10.2139/ssrn.3552671

Rühr, A., Streich, D., Berger, B. & Hess, T. (2019), A Classification of Decision Automation and Delegation in Digital Investment Systems, in: Proceedings of the 52nd Hawaii International Conference on System Sciences, 1435-1444.

Singh, I. & Kaur, N. (2017), Wealth Management Through Robo Advisory, *International Journal of Research - Granthaalayah*, 5(6), 33-43.

Tversky, A., & Kahneman, D. (1971), Belief in the law of small numbers, *Psychological bulletin*, 76(2), 105-110.

Uhl, M. W. & Rohner, P. (2018), Robo-advisors versus traditional investment advisors: An unequal game, *The Journal of Wealth Management*, 21(1), 44-50.

Ungeheuer, M., & Weber, M. (2021), The perception of dependence, investment decisions, and stock prices, *The Journal of Finance*, 76(2), 797-844.

Vieider, F., Villegas-Palacio, C., Martinsson, P. & Mejía, M. (2016), Risk taking for oneself and others: A structural model approach, *Economic Inquiry*, 2016, 54(2), 879-894.

Wärneryd, K.-E. (2001), Stock-market psychology, Cheltenham: Edward Elgar.

Zielonka, P. (2004), Technical analysis as the representation of typical cognitive biases, *International Review of Financial Analysis*, 13, 217–225.

Appendix 1: Instructions for the experiment

Instructions (Treatment Self)

You have the task of creating portfolios of shares. A portfolio of shares is a compilation of several shares.

The development of the share prices is of no concern to you, because you profit only once from the dividend payments of the shares in 2022. The dividend is the distribution of profits of a stock exchange-listed company to its shareholders.

You will receive information about how the dividend payments might turn out, and about the probabilities of different amounts of dividend. In addition, you will be shown how the dividends of the shares have developed over the last ten years.

You are paid the risk-adjusted dividend. A risk-adjusted dividend is the dividend payment divided by the variance of the dividend payments of the selected portfolio. Your task thus consists of achieving the highest possible dividends with the lowest possible risk (low variance).

The total of all risk-adjusted dividends (in ECU) which you achieve via your portfolio decisions is multiplied by five at the end and then paid in euros.

You can make the portfolio decisions yourself or delegate them to an algorithm (robo advisor). The robo advisor is specialised in making meaningful portfolio decisions and takes all of the relevant information into account in an optimal way in order to achieve risk-adjusted dividend payments which are as high as possible.

Instructions (Treatment Representative)

You have the task of creating portfolios of shares. A portfolio of shares is a compilation of several shares.

The development of the share prices is of no concern to you, because you profit only once from the dividend payments of the shares in 2022. The dividend is the distribution of profits of a stock exchange-listed company to its shareholders.

You will receive information about how the dividend payments might turn out, and about the probabilities of different amounts of dividend. In addition, you will be shown how the dividends of the shares have developed over the last ten years.

You are paid the risk-adjusted dividend. A risk-adjusted dividend is the dividend payment divided by the variance of the dividend payments of the selected portfolio. Your task thus consists of achieving the highest possible dividends with the lowest possible risk (low variance).

The total of all risk-adjusted dividends (in ECU) which you achieve via your portfolio decisions is multiplied by five at the end and then paid in euros. However, this amount is not paid to you, but to another participant. If you make successful decisions, one of the other participants will have something to be pleased about. If you make unsuccessful decisions, one of the other participants will be annoyed.

At the same time, another participant is making the decisions which determine your payment. Who has made portfolio decisions for whom will be announced at the end of the session.

So please remember why you made which decisions. The other participant might want you to justify your decisions if the results are disappointing.

You can make the portfolio decisions yourself or delegate them to an algorithm (robo advisor). The robo advisor is specialised in making meaningful portfolio decisions and takes all of the relevant information into account in an optimal way in order to achieve risk-adjusted dividend payments which are as high as possible.

Appendix 2: Test questions

Test questions (Treatment Self)

What is a share portfolio?

a) A compilation of shares, bonds and derivative instruments.
b) A compilation of shares. *(correct)*
c) A compilation of various securities without shares.

What is a dividend?

a) It is the opposite of a multiplication.
b) It is a major military unit.
c) It is the distribution of profits by a stock exchange-listed company to its shareholders. *(correct)*

What do you profit from?

a) From increases in the price of the shares that I choose.
b) From the risk-adjusted dividends of the shares that I choose. *(correct)*
c) From increases in the price of the shares that I choose, and from the dividends.

How can the algorithm (robo advisor) be deployed?

a) I have to use the robo advisor.
b) The robo advisor is not available to me.
c) I have a free choice between either making the portfolio decisions myself or delegating the task to a robo advisor which is specialised in this field. *(correct)*

Test questions (Treatment Representative)

What is a share portfolio?

a) A compilation of shares, bonds and derivative instruments.

b) A compilation of shares. *(correct)*

c) A compilation of various securities without shares.

From whose decisions do you profit?

a) From my own decisions.

b) From the decisions of all participants.

c) From the decisions of the participant who makes the decisions for me. *(correct)*

What determines the payment of the person for whom you make the decisions?

a) The changes in the prices of the shares that I choose.

b) The risk-adjusted dividends of the shares that I choose. *(correct)*

c) The increases in the price of the shares that I choose, and the dividends of the shares that I choose.

How can the algorithm (robo advisor) be deployed?

a) I have to use the robo advisor.

b) The robo advisor is not available to me.

c) I have a free choice between either making the portfolio decisions myself or delegating the task to a robo advisor which is specialised in this field. (correct)

Appendix 3: The tasks

Task 1 (Treatment Self)

There are two shares to choose from: share Y and share Z. The dividend payments of the two companies are independent random processes with two possible configurations: ECU 8 and ECU 0, and with an expected value of ECU 4. In the table you can see how high the dividend payments of the two shares were in the last 10 years.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Share Y	ECU 8	ECU 0	ECU 8	ECU 8	ECU 8	ECU 0	ECU 8	ECU 0	ECU 0	ECU 0	?
Share Z	ECU 0	ECU 0	ECU 8	ECU 0	ECU 8	ECU 8	ECU 0	ECU 0	ECU 8	ECU 8	?

You may choose two shares. As payment you receive the risk-adjusted dividends of the two selected shares. The risk-adjusted dividend corresponds to the dividend payment divided by the variance of the dividend payments of the selected portfolio. Depending on the portfolio selected, you thus receive the risk-adjusted dividends of 2 Y shares, of 2 Z shares, or of 1 Y share + 1 Z share. As the dividend payments are determined by a random process, it is not only the content of the portfolio which determines your payment, but also luck. Which event (ECU 8 or ECU 0) occurs in the case of the two shares is determined separately by drawing lots for each round of the experimental survey.

You can make the portfolio decisions yourself or delegate them to an algorithm (robo advisor). The robo advisor is specialised in making meaningful portfolio decisions and takes all of the relevant information into account in an optimal way. However, the robo advisor also does not know which random event (ECU 8 or ECU 0) will occur as the dividend of the shares. In other words, even when the robo advisor is used, luck determines the payment to a certain extent.

Now make your choice!

O I will let the robo advisor decide

I will decide myself and choose

O 2 Y shares

O 2 Z shares

O 1 Y share + 1 Z share

Task 2 (Treatment Self)

There are two shares to choose from: share X and share Q. The dividend payments of the two companies are independent random processes with two possible configurations: ECU 4 and ECU 0, and with an expected value of ECU 2. In the table you can see how high the dividend payments of the two shares were in the last 10 years.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Share X	ECU 0	ECU 0	ECU 4	ECU 0	ECU 0	ECU 0	ECU 4	ECU 4	ECU 4	ECU 4	?
Share Q	ECU 0	ECU 4	ECU 4	ECU 4	ECU 0	ECU 4	ECU 0	ECU 0	ECU 4	ECU 0	?

You may choose four shares. As payment you receive the risk-adjusted dividends of the four selected shares. The risk-adjusted dividend corresponds to the dividend payment divided by the variance of the dividend payments of the selected portfolio. Depending on the portfolio selected, you thus receive the risk-adjusted dividends of 4 X shares, of 4 Q shares, of 3 X shares + 1 Q share, of 3 Q shares + 1 X share, or of 2 X shares + 2 Q shares. As the dividend payments are determined by a random process, it is not only the content of the portfolio which determines your payment, but also luck. Which event (ECU 4 or ECU 0) occurs in the case of the two shares is determined separately by drawing lots for each round of the experimental survey.

You can make the portfolio decisions yourself or delegate them to an algorithm (robo advisor). The robo advisor is specialised in making meaningful portfolio decisions and takes all of the relevant information into account in an optimal way. However, the robo advisor also does not know which random event (ECU 4 or ECU 0) will occur as the dividend of the shares. In other words, even when the robo advisor is used, luck determines the payment to a certain extent.

Now make your choice!

O I will let the robo advisor decide

I will decide myself and choose

O 4 X shares

O 4 Q shares

O 3 X shares + 1 Q share

O 3 Q shares + 1 X share

O 2 Q shares + 2 X shares

Task 3 (Treatment Self)

There are two shares from a specific sector of industry to choose from (share K and share L). In the table you can see how high the dividend payments of the two shares were in the last 10 years. When business is good in the sector, the dividend of share K is ECU 6, and that of share L is ECU 7. When business is poor in the sector, the dividend of share K is ECU 2, and that of share L is ECU 1. The business situation in the sector can vary from year to year and thus has to be viewed as a random process: the probability of the business situation being either good or poor in 2022 is 50% in each case.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Share K	ECU 2	ECU 6	ECU 2	ECU 6	ECU 6	ECU 6	ECU 2	ECU 6	ECU 2	ECU 2	?
Share L	ECU 1	ECU 7	ECU 1	ECU 7	ECU 7	ECU 7	ECU 1	ECU 7	ECU 1	ECU 1	?

You may choose two shares. As payment you receive the risk-adjusted dividends of the two selected shares. The risk-adjusted dividend corresponds to the dividend payment divided by the variance of the dividend payments of the selected portfolio. Depending on the portfolio selected, you thus receive the risk-adjusted dividends of 2 K shares, of 2 L shares, or of 1 K share + 1 L share. As the dividend payments are determined by a random process, it is not only the content of the portfolio which determines your payment, but also luck. Which event (good or poor economic situation in the sector) occurs in the case of the two shares is determined separately by drawing lots for each round of the experimental survey.

You can make the portfolio decisions yourself or delegate them to an algorithm (robo advisor). The robo advisor is specialised in making meaningful portfolio decisions and takes all of the relevant information into account in an optimal way. However, the robo advisor also does not know which random event (good or poor economic situation in the sector) will occur as the dividend of the shares. In other words, even when the robo advisor is used, luck determines the payment to a certain extent.

Now make your choice!

O I will let the robo advisor decide

I will decide myself and choose

O 2 K shares

O 2 L shares

O 1 K share + 1 L share

Task 4 (Treatment Self)

There are two shares from a specific sector of industry to choose from (share M and share P). In the table you can see how high the dividend payments of the two shares were in the last 10 years. When business is good in the sector, the dividend of share M is ECU 4, and that of share P is ECU 3. When business is poor in the sector, the dividend of share M is ECU 0, and that of share P is ECU 1. The business situation in the sector can vary from year to year and thus has to be viewed as a random process: the probability of the business situation being either good or poor in 2022 is 50% in each case.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Share M	ECU 4	ECU 0	ECU 4	ECU 0	ECU 0	ECU 0	ECU 4	ECU 4	ECU 0	ECU 4	?
Share P	ECU 3	ECU 1	ECU 3	ECU 1	ECU 1	ECU 1	ECU 3	ECU 3	ECU 1	ECU 3	?

You may choose four shares. As payment you receive the risk-adjusted dividends of the four selected shares. The risk-adjusted dividend corresponds to the dividend payment divided by the variance of the dividend payments of the selected portfolio. Depending on the portfolio selected, you thus receive the risk-adjusted dividends of 4 M shares, of 4 P shares, of 3 M shares + 1 P share, of 3 P shares + 1 M share, or of 2 M shares + 2 P shares. As the dividend payments are determined by a random process, it is not only the content of the portfolio which determines your payment, but also luck. Which event (good or poor economic situation in the sector) occurs in the case of the two shares is determined separately by drawing lots for each round of the experimental survey.

You can make the portfolio decisions yourself or delegate them to an algorithm (robo advisor). The robo advisor is specialised in making meaningful portfolio decisions and takes all of the relevant information into account in an optimal way. However, the robo advisor also does not know which random event (good or poor economic situation in the sector) will occur as the dividend of the shares. In other words, even when the robo advisor is used, luck determines the payment to a certain extent.

Now make your choice!

O I will let the robo advisor decide

I will decide myself and choose

O 4 M shares

O 4 P shares

O 3 M shares + 1 P share

O 3 P shares + 1 M share

O 2 M shares + 2 P shares

Task 1 (Treatment Representative)

There are two shares to choose from: share Y and share Z. The dividend payments of the two companies are independent random processes with two possible configurations: ECU 8 and ECU 0, and with an expected value of ECU 4. In the table you can see how high the dividend payments of the two shares were in the last 10 years.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Share Y	ECU 8	ECU 0	ECU 8	ECU 8	ECU 8	ECU 0	ECU 8	ECU 0	ECU 0	ECU 0	?
Share Z	ECU 0	ECU 0	ECU 8	ECU 0	ECU 8	ECU 8	ECU 0	ECU 0	ECU 8	ECU 8	?

You may choose two shares. As compensation, the risk-adjusted dividends are paid from the two selected shares. The risk-adjusted dividend corresponds to the dividend payment divided by the variance of the dividend payments of the selected portfolio. Depending on the portfolio selection, the risk-adjusted dividend of 2 Y shares, of 2 Z shares, or of 1 Y share + 1 Z share is paid out. As the dividend payments are determined by a random process, it is not only the content of the portfolio which determines your payment, but also luck. Which event (ECU 8 or ECU 0) occurs in the case of the two shares is determined separately by drawing lots for each round of the experimental survey.

You can make the portfolio decisions yourself or delegate them to an algorithm (robo advisor). The robo advisor is specialised in making meaningful portfolio decisions and takes all of the relevant information into account in an optimal way. However, the robo advisor also does not know which random event (ECU 8 or ECU 0) will occur as the dividend of the shares. In other words, even when the robo advisor is used, luck determines the payment to a certain extent.

The payment which you achieve with your decision is received by one of the other participants and not by you. This other participant might ask you to justify your choices, so you should think carefully about the decisions you make.

Now make your choice!

O I will let the robo advisor decide

I will decide myself and choose

O 2 Y shares

O 2 Z shares

O 1 Y share + 1 Z share

Task 2 (Treatment Representative)

There are two shares to choose from: share X and share Q. The dividend payments of the two companies are independent random processes with two possible configurations: ECU 4 and ECU 0, and with an expected value of ECU 2. In the table you can see how high the dividend payments of the two shares were in the last 10 years.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Share X	ECU 0	ECU 0	ECU 4	ECU 0	ECU 0	ECU 0	ECU 4	ECU 4	ECU 4	ECU 4	?
Share Q	ECU 0	ECU 4	ECU 4	ECU 4	ECU 0	ECU 4	ECU 0	ECU 0	ECU 4	ECU 0	?

You may choose four shares. As compensation, the risk-adjusted dividends are paid from the four selected shares. The risk-adjusted dividend corresponds to the dividend payment divided by the variance of the dividend payments of the selected portfolio. Depending on the portfolio selection, the risk-adjusted dividend of 4 X shares, of 4 Q shares, of 3 X shares + 1 Q share, of 3 Q shares + 1 X share, or of 2 X shares + 2 Q shares is paid out. As the dividend payments are determined by a random process, it is not only the content of the portfolio which determines your payment, but also luck. Which event (ECU 4 or ECU 0) occurs in the case of the two shares is determined separately by drawing lots for each round of the experimental survey.

You can make the portfolio decisions yourself or delegate them to an algorithm (robo advisor). The robo advisor is specialised in making meaningful portfolio decisions and takes all of the relevant information into account in an optimal way. However, the robo advisor also does not know which random event (ECU 4 or ECU 0) will occur as the dividend of the shares. In other words, even when the robo advisor is used, luck determines the payment to a certain extent.

The payment which you achieve with your decision is received by one of the other participants and not by you. This other participant might ask you to justify your choices, so you should think carefully about the decisions you make.

Now make your choice!

O I will let the robo advisor decide

I will decide myself and choose

O 4 X shares

O 4 Q shares

O 3 X shares + 1 Q share

O 3 Q shares + 1 X share

O 2 Q shares + 2 X shares

Task 3 (Treatment Representative)

There are two shares from a specific sector of industry to choose from (share K and share L). In the table you can see how high the dividend payments of the two shares were in the last 10 years. When business is good in the sector, the dividend of share K is ECU 6, and that of share L is ECU 7. When business is poor in the sector, the dividend of share K is ECU 2, and that of share L is ECU 1. The business situation in the sector can vary from year to year and thus has to be viewed as a random process: the probability of the business situation being either good or poor in 2022 is 50% in each case.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Share K	ECU 2	ECU 6	ECU 2	ECU 6	ECU 6	ECU 6	ECU 2	ECU 6	ECU 2	ECU 2	?
Share L	ECU 1	ECU 7	ECU 1	ECU 7	ECU 7	ECU 7	ECU 1	ECU 7	ECU 1	ECU 1	?

You may choose two shares. As compensation, the risk-adjusted dividends are paid from the two selected shares. The risk-adjusted dividend corresponds to the dividend payment divided by the variance of the dividend payments of the selected portfolio. Depending on the portfolio selection, the risk-adjusted dividend of 2 K shares, of 2 L shares, or of 1 K share + 1 L share is paid out. As the dividend payments are determined by a random process, it is not only the content of the portfolio which determines your payment, but also luck. Which event (good or poor economic situation in the sector) occurs in the case of the two shares is determined separately by drawing lots for each round of the experimental survey.

You can make the portfolio decisions yourself or delegate them to an algorithm (robo advisor). The robo advisor is specialised in making meaningful portfolio decisions and takes all of the relevant information into account in an optimal way. However, the robo advisor also does not know which random event (good or poor economic situation in the sector) will occur as the dividend of the shares. In other words, even when the robo advisor is used, luck determines the payment to a certain extent.

The payment which you achieve with your decision is received by one of the other participants and not by you. This other participant might ask you to justify your choices, so you should think carefully about the decisions you make.

Now make your choice!

O I will let the robo advisor decide

I will decide myself and choose

O 2 K shares

O 2 L shares

O 1 K share + 1 L share

Task 4 (Treatment Representative)

There are two shares from a specific sector of industry to choose from (share M and share P). In the table you can see how high the dividend payments of the two shares were in the last 10 years. When business is good in the sector, the dividend of share M is ECU 4, and that of share P is ECU 3. When business is poor in the sector, the dividend of share M is ECU 0, and that of share P is ECU 1. The business situation in the sector can vary from year to year and thus has to be viewed as a random process: the probability of the business situation being either good or poor in 2022 is 50% in each case.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Share M	ECU 4	ECU 0	ECU 4	ECU 0	ECU 0	ECU 0	ECU 4	ECU 4	ECU 0	ECU 4	?
Share P	ECU 3	ECU 1	ECU 3	ECU 1	ECU 1	ECU 1	ECU 3	ECU 3	ECU 1	ECU 3	?

You may choose four shares. As compensation, the risk-adjusted dividends are paid from the four selected shares. The risk-adjusted dividend corresponds to the dividend payment divided by the variance of the dividend payments of the selected portfolio. Depending on the portfolio selection, the risk-adjusted dividend of 4 M shares, of 4 P shares, of 3 M shares + 1 P share, of 3 P shares + 1 M share, or of 2 M shares + 2 P shares is paid out. As the dividend payments are determined by a random process, it is not only the content of the portfolio which determines your payment, but also luck. Which event (good or poor economic situation in the sector) occurs in the case of the two shares is determined separately by drawing lots for each round of the experimental survey.

You can make the portfolio decisions yourself or delegate them to an algorithm (robo advisor). The robo advisor is specialised in making meaningful portfolio decisions and takes all of the relevant information into account in an optimal way. However, the robo advisor also does not know which random event (good or poor economic situation in the sector) will occur as the dividend of the shares. In other words, even when the robo advisor is used, luck determines the payment to a certain extent.

The payment which you achieve with your decision is received by one of the other participants and not by you. This other participant might ask you to justify your choices, so you should think carefully about the decisions you make.

Now make your choice!

O I will let the robo advisor decide

I will decide myself and choose

O 4 M shares

O 4 P shares

O 3 M shares + 1 P share

O 3 P shares + 1 M share

O 2 M shares + 2 P shares