DISCUSSION PAPER SERIES

DP13737

HOW TO ALLEVIATE CORRELATION NEGLECT

Martin Weber, Christine Laudenbach and Michael Ungeheuer

FINANCIAL ECONOMICS

ISSN 0265-8003

HOW TO ALLEVIATE CORRELATION NEGLECT

Martin Weber, Christine Laudenbach and Michael Ungeheuer

Discussion Paper DP13737
Published 15 May 2019
Submitted 13 May 2019

Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
www.cepr.org

HOW TO ALLEVIATE CORRELATION NEGLECT

Abstract

We experimentally study how presentation formats for return distributions affect investors' diversification choices. We find that sampling returns alleviates correlationneglect and constitutes an effective way to improve financial decisions. When participants get a description of probabilities for outcomes of the joint return distribution, we confirm the common finding that investors neglect the correlation between assets in their diversification choices. However, when participants sample from the joint distribution, they incorporate correlation into choices as predicted by normative theory. Results are robust across three experiments with varying expertise and experience of participants (students vs. investors), and varying return distributions (discrete, continuous).

JEL Classification: C91, G02, G11

Keywords: Investment Decisions, Diversification, Correlation Neglect, Risk Taking, Fintech

Martin Weber - weber@bank.bwl.uni-mannheim.de
University of Mannheim and CEPR

Christine Laudenbach - laudenbach@finance.uni-frankfurt.de
University of Frankfurt

Michael Ungeheuer - michael.ungeheuer@aalto.fi
Aalto University

How to Alleviate Correlation Neglect[a]

Christine Laudenbach, Michael Ungeheuer, and Martin Weber[b]

First Version: March 2017, This Version: May 2019

Abstract

We experimentally study how presentation formats for return distributions affect investors' diversification choices. We find that sampling returns alleviates correlation neglect and constitutes an effective way to improve financial decisions. When participants get a description of probabilities for outcomes of the joint return distribution, we confirm the common finding that investors neglect the correlation between assets in their diversification choices. However, when participants sample from the joint distribution, they incorporate correlation into choices as predicted by normative theory. Results are robust across three experiments with varying expertise and experience of participants (students vs. investors), and varying return distributions (discrete, continuous).

Keywords: Investment Decisions, Diversification, Correlation Neglect, Risk Taking, FinTech.

[a]We thank Peter Bossaerts, Dan Egan, Paul Gortner, Zwetelina Iliewa, Michael Kosfeld, Steffen Meyer, Robert Mislavsky, Monica Paiella, Diego Pulido, Nick Reinholtz, Marc Rieger, Oleg Urminsky, seminar participants at the University of Frankfurt, the University of Mannheim, the University of Heidelberg, and the University of Innsbruck, as well as conference participants at the Bogota Experimental Finance Conference 2018, the MPI (Max Planck Institute for Research on Collective Goods) Experimental Finance Workshop 2018, the BEAM Workshop Kyoto 2017, the Boulder Summer Conference on Financial Decision Making 2017, the Experimental Finance Conference 2017, DGF Meeting 2017, and CEPR European Workshop on Household Finance 2017. We are grateful to the team of the Frankfurt Laboratory for Experimental Economic Research. We gratefully appreciate funding from the German Research Foundation grant 993/15-1 (Weber).

[b]Christine Laudenbach: Goethe University Frankfurt, E-mail: laudenbach@finance.uni-frankfurt.de; Michael Ungeheuer: Department of Finance, Aalto University, E-mail: michael.ungeheuer@aalto.fi; Martin Weber: University of Mannheim, E-mail: weber@bank.BWL.uni-mannheim.de and the Centre for Economic Policy Research, London EC1V 3PZ, United Kingdom.

1 Introduction

One key element in making optimal investment decisions is diversification, which enables investors to reduce overall portfolio risk while holding return expectations constant. However, research has convincingly shown that people tend to underdiversify and ignore correlations in their asset allocation decisions. The aim of this study is to explore how to alleviate correlation neglect. To do so, we study how presentation formats for return distributions affect investors' diversification choices. In particular, we are the first to analyze whether sampling returns instead of directly receiving probabilities of joint returns descriptively helps investors incorporate correlation into their investment decisions.

Using an experimental setting, we show that participants diversify more when correlations are lower after sampling returns, which is in line with normative models (e.g., Markowitz, 1952). In contrast, we find that showing participants descriptions of probabilities for outcomes of the same joint return distribution results in correlation neglect. That is, participants' diversification choices do not respond to changes in correlation when they get a description of the joint distribution. Correlation neglect is in line with the experimental literature on diversification choice, which overwhelmingly uses descriptive presentation formats instead of sampling. Thus, our findings suggest that these previous results are induced by the design choice. Additionally, we find that sampling graphical return bars instead of sampling numerical returns is particularly effective in alleviating correlation neglect. Our results are robust in controlled laboratory experiments, in a field experiment with a heterogeneous group of actual investors with varying expertise and experience, and for more complex, continuous joint return distributions. Return sampling can be easily used in practical applications (e.g., in FinTech apps or online financial decision tools), making our findings particularly relevant as individual investors make more and more self-directed investment decisions.

Why should investors care about correlations at all? Diversification is often called "the only free lunch in finance." To capture diversification benefits, investors need to buy assets that tend to increase in value when other assets in their portfolio decrease in value (Markowitz, 1952), i.e., they need to incorporate correlation between assets into portfolio choice. However, investors seem to have a hard time capturing these diversification benefits. For example, investors take on more risk than necessary by holding underdiversified portfolios through a small number of different assets in their portfolio or by concentrating their investments on employer stocks or other familiar assets, such as in their home or local market (Bekaert, Hoyem, Hu, and Ravina, 2017; Benartzi and Thaler, 2007; Benartzi, 2001; Grinblatt and Keloharju, 2001; Lewis, 1999). Such stocks tend to crash when investors are hurting already as their careers and pensions naturally correlate with these stocks. If investors diversify, they tend to use naïve heuristics like a $1/n$-strategy (Benartzi and Thaler, 2001), instead of giving more weight to assets that provide more diversification benefits. Experimental studies also strongly indicate that investors tend to ignore correlations between assets (e.g., Eyster and Weizsäcker, 2016; Kallir and Sonsino, 2009; Kroll, Levy, and Rapoport, 1988).[1] So what can be done to alleviate correlation neglect in investment choice?

We propose that sampling from joint return distributions alleviates correlation neglect. Many ways to improve financial decision making have been discussed in the literature (e.g., Lusardi and Mitchell, 2014), but no effective ways to alleviate correlation neglect have been found so far. Findings on improving financial choice through education are mixed (e.g., Fernandes, Lynch, and Netemeyer, 2014). Instead, to derive our hypotheses, we use findings on the effects of personal experience on investors' risk taking. First, historical data indicate that risk perception and expectations are influenced by experienced returns (e.g., Malmendier and Nagel, 2011).[2] Second, the decision making literature shows that experiences can also be generated artificially, which can be effectively used to inform investors

[1]Kroll, Levy, and Rapoport (1988) were the first to document this correlation neglect in the financial domain. Participants in their experiment were asked to allocate an endowment between assets, where only the correlation between assets was varied across participants (from -0.8 to 0.8). They found that allocation was not affected by the treatment. This finding was also replicated in later studies (e.g., Eyster and Weizsäcker, 2016; Kallir and Sonsino, 2009): participants neglect correlations in their allocation decisions, even if they generally notice changes in co-movement.

[2]Malmendier and Nagel (2011) show that risk perception and expectations are influenced by experienced market returns over the life-time, while other studies show effects via personal or peer investment outcomes (e.g., Kaustia and Knüpfer, 2012; Strahilevitz, Odean, and Barber, 2011; Kaustia and Knüpfer, 2008), experiences in their local environment (e.g., Laudenbach, Loos, and Pirschel, 2017) or the experience of adverse labor market conditions (e.g., Knüpfer, Rantapuska, and Sarvimäki, 2017).

about potential risks. The idea is to enable investors to experience the return distribution with the help of a random sampling of possible returns. Several studies on sampling and risk taking show that providing participants with information about risk in an experience-based way, for example with the help of a simulation, as compared to a descriptive way, has the potential to increase the general understanding of risk and leads to more consistent investment decisions (e.g., Bradbury, Hens, and Zeisberger, 2015; Kaufmann, Weber, and Haisley, 2013; Hertwig, Barron, Weber, and Erev, 2004). Hence, generating an artificial experience of correlation through sampling from joint return distributions is a promising—and so far unexamined—tool to help investors diversify better.

To test whether sampling returns helps alleviate correlation neglect, we run three experiments: two controlled experiments in a computerized laboratory (Experiments 1 and 3) and one field experiment with actual individual investors (Experiment 2). The two laboratory experiments differ in their return distribution: Experiment 1 uses a discrete joint return distribution and Experiment 2 uses a more complex, continuous joint distribution. In all experiments, we vary correlation in a counterbalanced design within-subjects and presentation formats between-subjects. For our description presentation format, we use a design comparable to Kroll, Levy, and Rapoport (1988) or Kallir and Sonsino (2009), who communicate riskiness via probability statements. More precisely, participants are shown all potential joint return states of assets 1 and 2, as well as their respective frequency of occurrence. For our experience presentation formats, we use an experience-based sampling procedure to inform participants. That is, they are shown draws of joint returns of assets 1 and 2 based on the underlying distribution. We use two different formats: one numerical and one graphical format. To incorporate sampling, we build on the design of experiments from the experience sampling literature (Hertwig, Barron, Weber, and Erev, 2004; Kaufmann, Weber, and Haisley, 2013), where participants have to allocate an endowment between one risky and one risk-free asset. In our experiments, the returns of both assets are expressed in numbers in the numerical experience sampling treatment (e.g., 15% for asset 1 and −6% for asset 2). In the graphical experience sampling treatment, the same information is presented with the help of graphical bar charts. Both numerical and graphical experience sampling seem to be viable alternatives to alleviate correlation neglect ex ante and it is plausible that their effectiveness differs between investors (e.g., investors who are uncomfortable with numbers might prefer graphical sampling of returns).

For all three experiments, our experimental design for the diversification decision is based on Ungeheuer and Weber (2019). In two investment rounds, participants have to allocate an endowment between two assets that are more highly correlated in one of the rounds compared to the other, keeping everything else equal. In particular, marginal distributions do not change between the (counterbalanced) correlation conditions, so that only changes in dependence can explain treatment effects. Assets 1 and 2 are constructed in a way that asset 2 should only be selected due to its diversification potential.

In line with Eyster and Weizsäcker (2016), Kallir and Sonsino (2009), and Kroll, Levy, and Rapoport (1988), we confirm the common finding in the description-based literature that investors typically neglect correlation in diversification decisions. In Experiments 1-3 participants do not diversify significantly more when correlation decreases after seeing a description of joint returns. However, once we use an experience-based way of information presentation, they diversify more when correlation decreases. In Experiments 1 and 2, this finding is robust to sampling numerical returns or graphical bar chart returns. When we use a more complex continuous return distribution in Experiment 3, participants significantly change their asset allocations in response to changes in correlation only in the graphical experience sampling treatment, while the treatment effect after numerical experience sampling is attenuated. Additional robustness tests reveal that our results are not driven by the time spent looking at the return information, and hold controlling for sampling error or recency effects associated with experience sampling. Importantly, the heterogeneous sample in Experiment 2 allows us to show that the effect for graphical experience sampling holds for several subsamples: female investors, investors over age 50, investors with high statistical knowledge, risk-averse investors, as well as for investors who dislike numbers or are susceptible to framing. Overall, graphical experience sampling of return bars robustly alleviates correlation neglect in all three experiments.

Similar to the experiments in Ungeheuer and Weber (2019), our experiments are designed to find out *how* presentation formats affect the diversification decisions of investors, not *why*. Thus, while we get cleanly identified evidence on the effect of presentation formats on their diversification choices, we cannot clearly disentangle whether these formats affect investor choice through beliefs or preferences or both. Overall, we have some indications about the mechanism behind the success of sampling in alleviating correlation neglect. We discuss these indications as a point of departure for future research in Section 6.

Our paper contributes to several strands of the literature. First, it contributes to the literature on diversification choice. The traditional experimental literature on diversification choice uses descriptive presentation formats and concludes that investors neglect correlation in investment decisions (e.g., Eyster and Weizsäcker, 2016; Kallir and Sonsino, 2009; Kroll, Levy, and Rapoport, 1988). That is, investors do not increase diversification when correlation decreases, in contrast to the prescriptions by normative portfolio theory (Markowitz, 1952). Some more recent studies use sampling formats to present information and find that participants change diversification decisions in response to changes in dependence between returns. As an illustration, Wunderlich, Symmonds, Bossaerts, and Dolan (2011) show that participants can incorporate correlations into a variance minimization task after observing correlated outcomes over time. Participants have to play a resource management game combining different resources of electricity by adjusting weights that determine how the two resources are linearly combined. Participants are able to incorporate the covariance structure of the resources over time and the learning process is represented neurally. Ungeheuer and Weber (2019) also find that participants change their investment choices in response to changes in dependence when they observe a simulated 10-year time series of joint returns and prices. However, none of these more recent studies analyze how presentation formats affect diversification choice. We reconcile this recent experimental literature and the historical literature on diversification choices by investors by identifying a key driver of differences in results: sampling can alleviate the correlation neglect found with descriptive presentation formats.

Second, we contribute to the literature on personal experience and risk taking by testing the effect of artificial experience in a new domain: diversification choice. As discussed above in the motivation of our presentation formats, there is a growing literature on the effect of experience on beliefs and choices, both after natural experiences (e.g., Malmendier and Nagel, 2011) and after artificial experiences (e.g., Kaufmann, Weber, and Haisley, 2013). However, the effect of personal experience of joint return distributions on diversification choices of investors has not been analyzed in this literature, despite the essential importance of diversification in financial economics.

Third, we contribute to the literature on FinTech and financial education on the spot by providing a tool that can help investors incorporate correlation into investment choices, namely the sampling of return bars. This is particularly important today as private retirement planning becomes more relevant and the number of self-directed investment decisions increases. Practitioners are already providing clients with robo-advice tools that are intended to support their financial decision-making. Effective sampling procedures like the ones successfully tested in our experiments can be easily incorporated into such tools. Indeed, sampling procedures like the risk tool of Kaufmann, Weber, and Haisley (2013) have already served as an impulse for real-world tools used by financial institutions, and they could easily be enhanced to a two asset-case, so that investors can learn about the value of diversification.

2 Experimental Setup and Hypotheses

As motivated in the introduction, we experimentally test the following hypotheses on the effects of presentation format on investors' diversification choices:

H_1: Investors do not diversify more when correlation decreases if asset returns are presented in a descriptive way.

H_2: Investors diversify more when correlation decreases if asset returns are presented in an experience-based way.

H_1 is based on the existing evidence from the correlation neglect literature, whereas H_2 is motivated by the evidence from the experience-sampling literature. Testing both hypotheses within the same experimental design allows us to directly confront existing results on correlation neglect (H_1) with our new results on experience-based presentation formats (H_2). To test these hypotheses, we conduct two individual investment experiments in a computerized laboratory (Experiments 1 and 3) and one individual investment experiment in the field (Experiment 2).

2.1 Experimental task

Throughout all experiments, we ask participants to allocate an endowment of €10,000 between two risky assets. To define the joint distribution of the two assets' annual returns, we adapt the design in Ungeheuer and Weber (2019). Asset 1 has an average return of 5%, while asset 2 offers an average return of only 4%. Asset 2's return is achieved through a shift of asset 1's distribution by 1%, so that all higher moments (e.g., volatility or skewness) are equal across assets. Thus, the only reason to select asset 2 for the portfolio is its diversification potential. We use an allocation decision with only two assets and no risk-free asset to keep the investment decision as simple as possible.

After a short introduction, participants are informed about the risk-return profile of the two assets. The manner, in which this information is presented varies between participants. Participants are then asked how they want to allocate their endowment between the two assets. After the allocation decision, they answer questions about the perceived correlation and co-movement of the two assets and about their risk and return perceptions of their portfolio. Next, participants have to make another allocation decision, where everything is kept the same except the correlation between the two assets. After the allocation decision, participants are again asked questions about correlation, risk-return-perceptions, as well as additional control variables such as demographics. The experimental flow is illustrated in Figure A1 in Appendix A while all instructions and questions are reported in Appendix D.

2.2 Stimuli — Correlation

The two allocation choices differ only in the linear dependence between the two assets (counterbalanced within-subject design). Linear dependence means that the expected value of one asset's return is always linear in the other asset's return, i.e., $E(r_1|r_2) = a + b \cdot r_2$. Correlation is 0.6 in the first and -0.6 in the second condition.[3] In Experiments 1 and 2, we use two simplified assets, 1 and 2, with four different potential outcomes for each of them (see Table 1. In Experiment 3, both assets are normally distributed, but we keep the correlation stimuli the same as in Experiments 1 and 2 (0.6 and -0.6).

The co-movement between returns is lower in the low correlation as compared to the high correlation condition. Normatively, we would expect participants to diversify more once correlation decreases, because at lower correlations, there is a stronger reduction in portfolio variance for each unit of the diversification asset added (up to equal weighting). Figure 1 demonstrates the trade-off between risk and return and shows that the low correlation condition has much more potential to reduce portfolio variance at any given allocation. Figure 2 shows the optimal investment in asset 2 for an expected utility-maximizing investor with constant relative risk aversion (CRRA) at relative risk aversion from 0.5 to 10. A decrease in correlation (from 0.6 to -0.6) leads to a higher optimal investment in asset 2. Once again, the only reason for a reasonably risk-averse CRRA investor to invest in asset 2 is to diversify risk. With a decrease in correlation, the diversification potential of asset 2 increases, as does the optimal investment in asset 2. Increased relative risk aversion leads to a higher optimal investment in asset 2.

[3]We choose 0.6 and -0.6 with reference to Ungeheuer and Weber (2019); we do not believe that a change in the exact number of the coefficient would change our results. Kroll, Levy, and Rapoport (1988) use coefficients of (+/-) 0.8, while Kallir and Sonsino (2009) expose participants to correlation coefficients of (+/-) 1/3 and 2/3.

2.3 Stimuli — Presentation format

Participants are randomly assigned to one of the three presentation format treatments: description, numerical experience, or graphical experience. The three treatments differ in the way information about returns is presented. Through all treatments, returns are colored green if positive and red if negative, as is often done with real market data. To link our experiment to studies on correlation neglect, we use a description treatment, where we communicate the riskiness of returns via probability statements. More specifically, participants are shown one table with all potential joint return states of assets 1 and 2 and the respective frequency of occurrence. The table varies between conditions (high and low correlation). In the two experience treatments, participants are given information through an experience sampling procedure. More specifically, they have to make 60 draws of joint returns of asset 1 and 2 based on the underlying distribution. Participants know the number of draws from the beginning, as the progress is displayed on the screen (e.g., draw 5 out of 60). To induce experience sampling, we use two different formats: numerical and graphical. In line with Hertwig, Barron, Weber, and Erev (2004), the returns of both assets are expressed in numerical outcomes in the numerical experience treatments (e.g., 15% for asset 1 and −6% for asset 2). In the graphical experience treatment, we use a design based on Kaufmann, Weber, and Haisley (2013), where the same information is presented graphically with bar charts. For time reasons, we do not let participants draw a representative sample of 100 pictures, but make them draw 60 return pairs without replacement out of a representative sample of 100 return pairs. Hence the sampled observations differ by participants and decision round. This may induce a sampling error, which also has the potential to influence the allocation decision of participants (e.g., Hau, Pleskac, Kiefer, and Hertwig, 2008; Fox, 2006). We control for potential sampling error effects later in our analysis. Examples for all treatments are shown in Figure 3.

In Experiment 3, we change the design of the treatment relative to Experiments 1 and 2, as we use continuous joint return distributions for the risky assets.[4] We do this as follows:

[4]In Experiment 3 we additionally toyed with a graphical description treatment (see Figure A2), which

In our description treatment, we again communicate the riskiness of returns via probability statements. As distributions are now continuous, we use return ranges in the probability statements. More specifically, participants are shown one table with potential joint return ranges of assets 1 and 2 and the respective frequency of occurrence (see Panel C of Figure 3).[5] The frequencies of occurrence for the respective joint realizations again vary between conditions (high and low correlation). To ease understanding, we include reading examples like the following: "In 10 out of 100 cases, asset 1 has an annual return between -5% and 5%, while asset 2 at the same time has an annual return between 5% and 15%."

In the two experience treatments, participants are presented information through the experience sampling procedures, as in Experiments 1 and 2. The graphical and numerical experience sampling formats provided do not look different with regard to their design in comparison to Experiments 1 and 2; the variation in different outcomes that can be observed is of course much higher. Therefore, we use a stratified random sampling method to reduce the sampling error when generating the 60 different return pair draws for each participant in both of the two experience treatments.[6]

2.4 Beliefs and additional control variables

To test, whether participants ignore correlations or simply misunderstand them, we ask questions about general dependence (e.g., "asset 1 and asset 2 move together / into opposite directions"; "if asset 1 increases, I expect asset 2 to increase / decrease"), as well as the exact frequency of co-movement ("if asset 1 increases, I expect asset 2 to increase in ... out of 100 cases") in all three experiments.

could not help alleviate correlation neglect, but rather led to more diversification in the high correlation condition, i.e., a normatively worse investment decision than under the numerical description format. We suspect the graphical description was too hard to understand for participants. We report results for this treatment in the Appendix, in Tables B11 and B12, and discuss results in Appendix C.

[5]Although probabilities for return ranges provide only a coarse picture of the continuous normal distribution, we think this preferable to alternative descriptive presentations, e.g., probability density functions, which would be much harder to understand for participants without a profound background in statistics.

[6]Stratification in this context means that we divide the distribution's support into 60 equally likely subranges before sampling. Participants are then provided with one return pair out of each subrange in random order.

After the second decision, participants are asked for demographics, which might be related to diversification behavior. We ask for their gender, age, background in statistics and finance, as well as their self-assessed risk aversion. We also ask twelve financial literacy questions from Fernandes, Lynch, and Netemeyer (2014) and the four numeracy questions from Cokely, Galesic, Schulz, and Ghazal (2012). In Experiment 2, the field experiment with actual investors, we enrich the data set with questions on real investment behavior and attitudes (e.g., participants trading frequency or their interest in financial markets). Table B1 gives an overview of the outcome variables (Panel A) and control variables (Panel B). Appendix D presents all instructions and questions for all three experiments, translated to English.

2.5 Payment

Participants are paid in an incentive-compatible manner. In the laboratory experiments (Experiments 1 and 3), one of the two investment choices is randomly selected for payoff. To determine the final outcome, one random return pair is drawn out of the underlying distribution, multiplied with the shares of the 10,000 € endowment the participant allocated to the respective assets and divided by 1,000. Example: If a participant invested 70% in asset 1 and 30% in asset 2 in round 1 and the random draw revealed round 1 with a return of -6% for asset 1 and 15% for asset 2, her payment is: (0.7*10,000*(1-0.06)+10,000*(1+0.15))/1,000=10.03 €. Participants on average received a payoff of 10.37 € for a one-hour experiment session including instructions and payment. In the field experiment (Experiment 2), every participant was given a 5 € Amazon voucher. Every 10$^{\text{th}}$ participant (determined by a lottery) was paid based on the same formula as in the laboratory experiments. These amounts were also paid out using Amazon vouchers sent via email.

3 Experiment 1: Baseline Results

In Experiment 1, we test the the effect of description- and sampling-based presentation formats on correlation neglect (H_1 and H_2) in a University laboratory setting. This experiment provides a highly controlled baseline result for our subsequent online experiments with actual investors (Experiment 2) and another University laboratory experiment with a more complex, continuous joint return distribution (Experiment 3).

3.1 Data and participants

Experiment 1 was conducted in May 2016 at the Frankfurt Laboratory for Experimental Economic Research with 286 participants. The laboratory is a research center at the Faculty of Economics and Business Administration at Goethe University Frankfurt. The software packages Orsee (Greiner, 2003) and z-Tree (Fischbacher, 2007) were used to conduct the experiment. The participant pool was mainly university students. Summary statistics are reported in Panel A of Table 2.

Participants are on average 22 years old and 70% of them have taken a statistics course, so that the majority should be familiar with the concept of correlations, although we never mention the term "correlation" in our experiments. Note that the experimental randomization worked, as we find no statistically significant differences in personal characteristics between treatments.

3.2 Asset allocation decisions

Table 3 reports our main result for Experiment 1. It gives an overview of the share invested in asset 2 by treatment and condition. We would expect participants not to change their allocation for the description treatment, in line with correlation neglect (H_1). This is exactly what we find: participants invest on average even a (insignificantly) 2.06% higher amount (33.08%) in asset 2 in the high compared to the low (31.02%) correlation condition. In contrast, in the experience treatments, participants diversify less in the high compared to the low correlation condition, as is optimal for a risk-averse investor. Participants allocate on average 7.37% (10.62%) less in asset 2 in response to correlation changes in the numerical (graphical experience) treatment, in line with experience sampling alleviating correlation neglect (H_2). Looking at participants' allocations in a between-subject design, we find that the degree of diversification in response to correlation-changes increases significantly from description to experience treatments (t-stats of 2.54 and 3.62 for numerical and graphical experience, respectively). Note that the graphical experience treatment results in a diversification effect (10.62%) that is one-third stronger than the numerical experience sampling treatment's diversification effect (7.37%); this difference is, however, statistically insignificant.

Next, we analyze the influence of presentation format on investment decisions using a random effects regression model with the share invested in asset 2 as the dependent variable. We run random effects regressions to take participant-specific effects into account. Since the treatment is orthogonal to participant characteristics, random effects regressions are justified. The results for Specification (1) in Panel A of Table 4 confirm our previous findings from Table 3. In the low correlation condition in the description treatment, participants invest an average of 31% in asset 2. For participants in the experience treatments, this share is generally higher and, more importantly, significantly increases with a change from high to low correlations, in particular after the graphical experience treatment. Adding control variables to our analysis does not alter our results. If we, for example, add risk attitude to our regression, we find a positive and economically sensible, but insignificant effect on the decision to diversify (see Table B2 in Appendix B).

We next analyze some alternative factors that may drive our results, but are not based on the difference in the presentation format itself. In the first test, we exclude participants who might not have understood the general diversification potential of asset 2. Asset 2 has a lower return but the same marginal distribution as asset 1; it should thus only be interesting because of its diversification potential up to a weight of 50%. In Specification (2), we exclude investors who invest more than 50% in asset 2 and find that results are robust to the exclusion of these participants. The results get a little weaker for the numerical experience treatment and stay similar for the graphical experience treatment if we restrict the sample to participants who have taken a statistics course or report they are interested in financial markets.

Every participant in our experiment has to make two investment choices: the first in the low correlation condition, the second in the high correlation condition, or vice versa. One could argue that the second decision is influenced by the first, as participants already know more about the decision-making process, thus perceive or collect the information presented differently. Therefore, we restrict our sample to participants' first decision only in Specification (3). The results hold and reveal that the effect of presentation formats is present within (Specification 1), as well as between-subjects (Specification 3). Nevertheless, participants may learn over the course of the experiment. In Specification (4), we test whether participants show a systematically different allocation behavior in the second decision round as compared to the first. We estimate both the direct effect of a second-round dummy on the investment in asset 2, as well as the interaction between the second-round dummy and the correlation dummy. Both of these coefficients are statistically insignificant and economically close to zero. We thus do not find the participants exhibit a learning effect. This is in line with the results of Kroll, Levy, and Rapoport (1988), who also do not find a session-to-session change in allocation.

Fox (2006) suggests that differences in choice when comparing descriptive and experience-based presentation formats may also be explained by recency effects or sampling error. In our setup, this could be the case if participants incorporate diversification differently for various values of correlation. If, in an extreme case, participants reacted only to correlations larger than 0.8, sampling errors or recency effects could bias our results. We therefore test whether the sampled return-pairs (first, last, as well as the associated sampling error for correlation) have an effect on our result. In Specification (2)-(4) of Panel B of Table 4, we include the last (Specification 2) or the first (Specification 3) sampled return-pairs' correlation, or the first and last two sampled returns (Specification 4). We exclude the description treatment for these tests ((1)-(4)), since it exhibits no variation in observed returns. Specification (1) reports results for this subsample of presentation formats. The effect of correlation on diversification in the numerical experience treatment can be seen in the coefficient for the correlation dummy, which is 7.37%. More importantly, the effects of correlations and returns experienced first or last in the sampling procedure are weak. There is only one barely statistically significant result: A high correlation for the first return pair decreases diversification by 4.21%. We still find that participants significantly respond to shifts in correlation in the experience sampling treatments: the coefficient of the high correlation dummy is significant for Specifications (1) to (4) at between 5.35% to 7.31% less diversification; the interaction between the correlation dummy and the graphical experience dummy indicates a slightly (but insignificantly) stronger effect for graphical relative to numerical experience.

Next, we test whether sampling error can explain differences in diversification between presentation formats. Participants in our experience treatments cannot, in contrast to participants in the description treatment, know what a representative sample of the distribution would be, as they only sample 60 observations from a sample of 100 representative observations (random draws without replacement). The resulting average correlation is +0.6 in the high correlation condition, and -0.6 in the low correlation condition, but with a between-subjects range of -0.3 to -0.8 and 0.3 to 0.8 from minimum to maximum realized correlations, respectively. Figure 4 shows the distribution of realized correlations across treatments. We see that there is indeed variation in the realized correlation due to the randomization of 60 out of 100 potential draws by participant. In Specification (5) of Panel B of Table 4, we include all participants in the description treatment, but limit our analysis to participants in the experience treatments, whose sampling error is small, namely who realize a correlation between -0.65 and -0.55 in the low correlation condition and between 0.55 and 0.65 in the high correlation condition. Results also hold for this specification, and show that the effect is not due to sampling error.

One alternative explanation is that the effect of experience sampling on correlation neglect is not driven by the sampling itself, namely the way the information is presented, but rather by the time needed to collect this information. Generally, participants can take as long as they want to respond, but the minimum time they need in the description treatment is lower than for the experience treatments, as participants have to view one picture in the former treatment and 60 pictures in the latter treatments. Figure A3 in Appendix A shows the time spent per picture by treatment and condition. Panel A of Table 5 reports the average time spent viewing the information about asset returns by treatment. The time spent in both experience treatments, 110 seconds in the numerical and 106 seconds in the graphical experience, is significantly higher than the 75 seconds spent in the description treatment (t-stats of 5.76 and 4.91 respectively). There is no significant difference between the numerical and the graphical experience treatments. The viewing times are similar across correlation conditions, but significantly different in the two rounds. Participants in the description treatment spend significantly more time on the description in round 2 (82 seconds versus 68 seconds), participants in the experience sampling treatments significantly decrease their viewing times from round 1 to round 2 (e.g., from 122 seconds to 89 seconds for graphical experience).

It is plausible that spending more time viewing the information might improve the diversification decision. Panel B of Table 5 shows the investment into asset 2 split by participants who spent above- and below-median time to view information about asset returns. The results are very similar for both subsamples. Hence, longer viewing times do not seem to drive the positive effect of sampling on correlation neglect. Participants who spend less time actually react more strongly to the correlation stimulus, but this effect is weak and statistically insignificant. We generally expect participants to spend more time in the first decision round as they become more familiar with the environment and therefore need less time to process information in the second round. Interestingly, we find that participants in the experience treatments spent more time in the first decision round compared to the second round, while the effect is reversed, however insignificantly, for participants in the description treatment. This finding suggests participants may feel more confident in their decision-making in the experience treatments. After each decision, we ask participants about their level of confidence confidence; participants indeed report a (marginally) significantly higher confidence in the graphical experience treatment (4.38 out of 5 on a Likert scale) as compared to the description treatment (4.11 out of 5). However, we find no significant difference in confidence between the numerical experience and the other two treatments. We also do not find differences between treatments in how informed participants feel when making their investment decision (again see Appendix D for the exact wording of questions). Furthermore, our results hold if we weight observations in the experience sampling treatments by viewing times, namely the time the participants looked at each picture. Overall, we find that experience sampling robustly alleviates the correlation neglect in diversification decisions after a description-based presentation format, in line with hypotheses H_1 and H_2.

3.3 Perceptions of dependence and risk

Panel A of Table 6 reports participants' beliefs about dependence between asset returns. We find that participants move their answers in the right direction in response to correlation changes in all treatments. The effect is, however, weaker in the description treatment. In both experience treatments, participants clearly note the shift in dependence and are more accurate about it than they are for the description treatment.[7] Panel A of Table 6 shows that the majority of participants in both the numerical treatment (52 of 96) and the graphical experience treatment (62 of 92) note that assets 1 and 2 move in opposite directions in the low correlation condition (correlation of -0.6), while this is only the case for a minority of participants (38 of 98) in the description treatment. In the high correlation condition (correlation of +0.6), the majority of participants in the numerical experience treatment (68 of 96) and the graphical experience treatment (57 of 92) note that assets 1 and 2 move together, while this is only the case for a small minority of participants (21 of 98) in the description treatment.

When we vary the question about correlation perception, the results turn significant between correlation conditions in the description treatment, but stay markedly weaker than for the experience treatments. In these alternative questions, we ask for example whether asset 2's price tends to increase or decrease if asset 1 decreases. We also ask about the

[7] The exact question asked is shown in Panel A of Table 6 and listed in Appendix D.

frequency of co-movement, i.e., the frequency of same-signed return pairs.[8] The results for alternative questions are in Table B3 in Appendix B. Overall, the effects sizes for the experience sampling treatments are around three to six times larger than the effect sizes for the description treatment, consistent with participants being able to form more accurate beliefs in the experience sampling treatments as compared to the description treatment.

Next, we analyze whether participants accurately understand portfolio risk. Diversification is valuable because it reduces portfolio risk. Reinholtz, Fernbach, and de Langhe (2016) show that participants in their experiment (wrongly) believe that diversification increases portfolio volatility, which leads to portfolios that do not match investors' risk preferences. So far, we have only analyzed participants' beliefs about dependence. Can participants properly use their knowledge about correlations to estimate overall portfolio risk? To find out, we ask participants to estimate the probability of a portfolio loss. Bradbury, Hens, and Zeisberger (2015) show the importance of loss probabilities in explaining investor behavior for allocations between a risky asset and a risk-free asset. However, in our experiment, the frequency of losses cannot be directly estimated from the sampled return pairs or seen in the description of the joint return distribution. Participants need to combine their chosen portfolio weight with the joint return distribution of assets 1 and 2 to estimate loss probabilities. This is a cognitively challenging task. We report the results for estimated versus true loss probabilities in Panel B of Table 6.

In Panel B of Table 6, we find that the effect of changes in correlation on the true probability of loss is strong for the average participant's portfolio decision. For the description treatment, the true loss probability increases by over 17 percentage points from the low to the high correlation condition. For the numerical (graphical) experience treatment, the increase in true loss probability is even larger at over 22 percentage points (24 percentage points). This strong effect is driven by the change in correlation between conditions. At a lower correlation, the likelihood of joint bad returns becomes smaller, so that portfolio-level

[8]In line with Matthies (2018), we find that participants generally underestimate dependence, especially in the description treatment. Note that a bias towards the middle is expected: The bounded range of answers will naturally lead to large errors due to noise being more likely towards the middle answer categories.

losses become unlikely. In addition, the investment choice made by participants has an enhancing effect. Therefore, the higher level of diversification in the sampling treatments under lower correlation further reduces the loss probability. However, participants' estimates for the loss probability do not increase by more than 1 percentage point from the low to the high correlation condition and these increases are statistically insignificant. The estimated probability of loss even decreases by 5 percentage points for the numerical experience treatment (statistically significant at the 10% level). Hence, we find that participants are not able to use their accurate understanding of correlations to properly assess portfolio risk.[9]

This result does not contradict our previous finding that correlation neglect is alleviated when sampling is used as a presentation format. Results on the perception on dependence clearly show that participants understand dependence on a state-by-state basis in the experience treatments. Their investment decisions in Table 3 are in line with this accurate understanding of dependence. The misestimation of portfolio risk in Panel B of Table 6 just shows that participants are not able to aggregate correct state-by-state beliefs to the portfolio level. It is not necessary to perform the challenging task of aggregating individual assets' return distributions to the portfolio's return distribution (Reinholtz, Fernbach, and de Langhe, 2016) in order to adequately react to changes in correlation. Understanding what happens to asset 2 when asset 1 decreases in value is enough for participants to grasp the value of diversification. Nevertheless, it seems that there is a need for further research on investors' understanding of joint asset return distributions and their ability to aggregate asset return distributions to portfolio return distributions when making diversification decisions.

Overall, we find that sampling helps to alleviate correlation neglect in asset allocation decisions and our results are robust to excluding participants with unreasonable levels of diversification, using a pure between-subjects design (results from the first round only) or controlling for sampling error as well as decision-making times. This experiment was conducted with a relatively homogeneous group of participants in a computerized laboratory.

[9] We also do not find significant differences between conditions or treatments if we look at alternative measures for the risk-return profile of the overall portfolio like the probability of a large gain, the probability of a large loss or the expected portfolio return (see Table B13 in Appendix B).

In this highly controlled setting, we find baseline results in line with both hypotheses H_1 and H_2.

4 Experiment 2: Stability in the Field

In Experiment 2, we test the stability of our baseline results from Experiment 1 for a sample of actual investors in an online field experiment. This experiment provides a test of external validity for a sample of participants with higher levels of expertise and investment experience. The heterogeneity of the sample also enables us to analyze whether treatment effects interact with participant characteristics (e.g., whether participants with more investment experience also show correlation neglect in the description format).

4.1 Data and participants

Experiment 2 was conducted online in September 2018 with 446 participants. We aimed for a 50% larger sample size compared to the laboratory Experiments 1 and 3 (where we have around 300 participants per experiment) because of concerns about power in this less controlled setting. Experiment 2 was programmed and conducted with oTree (Chen, Schonger, and Wickens, 2016). Participants were recruited with the help of an email list administered by the University of Mannheim. The people on this list have taken part in one of several, unrelated studies. These studies were advertised in the financial section of large German newspapers and participants indicated that they are willing to participate in future studies. We invited everyone on the list (6,015 people) to participate in our experiment, which leaves us with a final response rate of 7.4%.[10] This sample may not be representative of the German population or even for the average German investor, since the recruitment process may induce a selection bias, which we can not control for. The intention of this experiment

[10]Overall, 1,148 people clicked on the email link to the survey. If we analyze attrition in more detail, we find that attrition is lower in the graphical sampling treatment: 57% in the graphical sampling treatment versus 63% in the description and 63% in the numerical sampling treatment. Forty-seven percent of participants who drop out do this on the introductory and instruction pages, while 27% depart the study on the information presentation page.

is, however, to contrast the student sample for Experiment 1 with a group experienced in investing to test whether our results hold in a markedly different group. Within the sample, participants vary substantially in personal and investment characteristics like age, wealth or trading frequency, which allows us to test the treatment effect for different subgroups of investors. Summary statistics are reported in Panel B of Table 2. Their personal characteristics differ markedly from the subject pool in Experiment 1. Participants in Experiment 2 are on average 51 years old, the majority is male (89%), reports to be interested in financial markets (98%), holds equity (92%), and reports trading at least once a year. The willingness to take financial risk is higher as compared to the student sample (3.46 vs 2.63). With regard to the experimental randomization, we do not observe any statistically significant differences in personal characteristics between the three presentation format treatments.

4.2 Asset allocation decisions

Consistent with the results for Experiment 1, we find in Table 7 that participants on average diversify less in the high correlation condition than the low correlation condition, as is optimal for a risk-averse investor. The effect is again statistically significant for the experience treatments (H_2) and we do not find significantly different allocations between the correlation stimuli in the description treatment (H_1).

More precisely, participants allocate on average 6.66 (14.87) percentage points less in asset 2 in response to correlation changes in the numerical (graphical) experience treatment, while the difference is 1.88 percentage points in the description treatment. Looking at participants' allocations in a between-subject design, we find that the degree of diversification in response to correlation changes increases significantly from description to numerical experience to graphical experience. Again, the graphical experience treatment results in a diversification effect, which is markedly stronger than the numerical experience treatment's diversification effect; in contrast to Experiment 1, in Experiment 2 the difference is also statistically significant. If we analyze the influence of presentation format on investment decisions in a random effects regression model with the share invested in asset 2 as the dependent variable, we still find that—relative to the description treatment—the treatment effect of correlation on diversification is higher for the experience treatments. This effect is statistically significant for the graphical experience treatment (at the 1% level). For the numerical experience treatment, it is statistically insignificant, although the confidence interval includes the economically significant values we find for Experiment 1. The results are reported in Table B4 in Appendix B. In Experiment 2, we also find a significant (positive) effect of risk aversion on the decision to diversify (see Table B2 in Appendix B). Again, the results hold when we control for recency or sampling error (see Table B5 in Appendix B).

The subject pool that we use in Experiment 2 provides us with the opportunity to test whether the influence of presentation formats is stable or interacts with different investors characteristics. In Figure 5, we summarize the average investment shares in diversification asset 2 for the high correlation condition and the low correlation condition by treatment for different subsamples of participants. The bars in the graphical experience treatment reveal that allocations to the diversification asset 2 increase significantly with a decrease in correlation across all, even quite small, subsamples. In line with the average findings in both Experiments 1 and 2, the results for the numerical experience treatment are statistically weaker and turn insignificant for the subsample of investors older than 50 years as well as for the small female subsample. When we look at different subsamples in the descriptive treatment, we find a statistically significant effect for one subgroup only, namely for participants who mistakenly think that diversification increases expected returns. This difference is nevertheless much weaker than differences in the experience treatments. In general, differences in economical magnitudes across treatments can be recognized at first glance, with hardly discernible effects in the description treatment and clear effects in the graphical experience treatment. It might be surprising that even subsamples that have a lot of trading experience and knowledge about statistics do not diversify significantly more when correlation is low in the description treatment. However, investment experience, education, and a sharp intellect do not necessarily alleviate correlation neglect, as illustrated by John Maynard Keynes' statement: "It is a mistake to think that one limits one's risks by spreading too much between enterprises about which one knows little and has no reason for special confidence" (letter from Keynes to F. C. Scott, 1934). Overall, the results for Experiment 2 provide strong evidence that graphical experience sampling of returns robustly alleviates correlation neglect, in line with H_1 and H_2.

4.3 Perceptions of dependence and risk

Panle A of Table 8 reports participants' beliefs about dependence. Again, we find that participants answer appropriately in response to correlation changes in all treatments. Panel A of Table 8 shows that 45% of participants in the graphical experience treatment (74 of 163) note that assets 1 and 2 move in opposite directions in the low correlation condition (correlation of -0.6) followed by 43% of respondents in the numerical experience and 32% of respondents in the description treatment. The results for the high correlation condition are similar: 29% in the description treatment, 50% in the numerical experience treatment, and 54% of respondents in the graphical experience treatment note that assets 1 and 2 move together. Between-subjects, the accuracy in perception is again significantly weaker in the description treatment. The results on alternative questions for the perception of dependence are reported in Table B6 in Appendix B. In addition, we also assessed participants' perception of portfolio risk the same way as we did in Experiment 1. Again, we find that participants are neither able to use their accurate understanding of correlations to properly assess the probability of loss (Panel B of Table 8) nor alternative measures of portfolio risk (Appendix B, Table B13).

The heterogeneous subject pool in Experiment 2 gives us the opportunity to analyze whether the influence of the presentation formats on the perception of dependence is stable or interacts with participant characteristics. Figure 6 reveals that perceptions of dependence are stable across personal characteristics and treatments and are with two exceptions (the group of females in both the description treatment as well as the numerical experience treatment) highly significant. The figure also shows that the magnitude of the difference gets stronger from the description treatment to the numerical experience treatment and from the numerical experience treatment to the graphical experience treatment. Overall, these results reveal that sampling returns has the potential to increase participants' understanding of dependence, but participants are already capable of detecting changes in dependence in the descriptive presentation format.

5 Experiment 3: Robustness to Complex Return Distribution

In Experiment 3, we test the the robustness of our baseline results from Experiment 1 under a continuous joint return distribution in a University laboratory setting. This experiment provides a highly controlled robustness test in a more complex scenario.

5.1 Data and participants

Experiment 3 was conducted in November and December 2016 at the Frankfurt Laboratory for Experimental Economic Research with 303 participants. Participants who had taken part in Experiment 1 were excluded from the subject pool. Summary statistics are reported in Panel C of Table 2. Personal characteristics are comparable to those reported in Experiment 1. Participants on average received a payment of 10.27 € for a one-hour session including instructions and payment.

In Experiment 3, we increase the complexity of the return distribution, but keep general return parameters equal: like in Experiments 1 and 2, asset 1 has an average return of 5%, while asset 2 offers an average return of only 4%; the volatility of both assets is set to 13%. Correlations are again -0.6 and +0.6 in the two correlation conditions. However, returns are now jointly normally distributed. An example of the pictures provided is provided in Figure 3.

5.2 Asset allocation decisions

In Table 9 we report the share invested in diversification asset 2 by presentation format treatment and correlation condition. We replicate the alleviation of correlation neglect under graphical experience, which we also find in Experiments 1 and 2. Specifically, we find that participants again do not significantly change their allocation in the description treatment (difference between low and high correlation of 1.62 pp), in line with correlation neglect H_1. But in the graphical experience treatment they diversify significantly more in the low correlation condition than in the high correlation condition (difference of 8.02 pp), in line with H_2. The difference-in-difference between the two presentation formats is economically smaller compared to Experiments 1 and 2, but still significant at the 10% level.

In the numerical experience treatment, we find that participants do not significantly change diversification choices in response to correlation changes (difference of 0.64 pp). This is consistent with the smaller effects after numerical experience relative to graphical experience in Experiments 1 and 2 (see Tables 3 and 4 as well as Figure 5). Our more complex return distribution in Experiment 3 seems to reduce the diversification effects in both experience sampling treatments relative to Experiment 1, which leads to insignificant diversification effects for the numerical experience treatment. This lower diversification effect for the numerical experience treatment is also found when we focus on the participants with above-median viewing times (see Table B9 in Appendix B). Why does graphical experience lead to stronger diversification effects than numerical? The information given in that context is rather complex. The success of graphical experience in alleviating correlation neglect, in particular in Experiment 3, may be driven by the fact that the graphical experience sampling procedure helps investors to incorporate information into their choice, even if the decision gets more complex, whereas the numerical description or numerical experience treatments do not.

The results also hold in a random effects regression framework (see Table B7 in Appendix B). The effect stays negative and turns insignificant when we reduce the sample size by excluding participants who invested more than 50% of wealth into asset 2 or when we just focus on the first (out of two) round of the experiment.[11] The results also hold if we control for recency effects of the first and last draws in returns or their correlations (see B8 in Appendix B) and stay economically similar, but turn insignificant when we use a smaller sample and exclude participants from the experience sampling treatments that happened to sample a correlation outside the ±5 percentage point range around the true underlying correlation (-0.6 or +0.6). Generally, the diversification effects in Experiment 3 are weaker than those in Experiments 1 and 2. One potential explanation in addition to the increased complexity of a continuous return distribution is the smaller variation in the frequencies of the co-movements (jointly positive or jointly negative returns), even though the variation in correlations across conditions remains the same (-0.6 and +0.6). Figure 7 depicts the realized correlations and co-movements for all three experiments. Although the realized correlations for the experience treatments are comparable between the three experiments, the graphs reveal that there is a clearly lower variation in realized co-movements in Experiment 3, relative to Experiments 1 and 2.

While the fraction of realized co-movement varies between 0.2 and 0.8 in Experiments 1 and 2, it varies between 0.36 and 0.72 in Experiment 3, making the stimulus around 40% weaker. Since participants seem to perceive dependence based on the frequencies of return co-movement rather than on correlation (Ungeheuer and Weber, 2019), the smaller effect sizes we find in Experiment 3 are not surprising.

Overall, we find that the graphical experience treatment has a robust positive effect on the participants' responsiveness to correlation changes in asset allocation. That is, graphical experience alleviates correlation neglect, in line with H_2. At the generally lower effect sizes for the more complex continuous return distributions in Experiment 3, numerical experience becomes ineffective in alleviating correlation neglect.

[11] We do not learn much from these results, however, because the low power of these tests leads to very wide confidence intervals, which include economically large effects.

5.3 Perceptions of dependence and risk

Panle A of Table 10 reports participants' beliefs about dependence between asset returns in Experiment 3. In line with Experiments 1 and 2, we find that participants respond appropriately to correlation changes within all presentation format treatments. Between treatments, the differences in perception of dependence are different from Experiments 1 and 2. For the overall dependence question, the results are no longer weaker in accuracy for the description treatment compared to the numerical and graphical experience treatments. This also holds for the alternative questions except the second co-movement question, where we still find a significant difference between the description treatment and the graphical experience treatment (see Appendix B, Table B10). In Experiment 3, the participants additionally have a choice to check a "do not know" option. Dependent on the question, between 8% and 13% of participants state that they do not know the answer. The results here are also mixed. While a (insignificantly) higher fraction of participants seems to be unsure in the description treatment compared to the graphical experience treatment with regard to the overall dependence question, the results are opposite and significant for the alternative dependence questions we report in Table B10 in Appendix B.

In Experiment 3, we do not find any evidence that participants' beliefs are more accurate about dependence in the graphical experience treatment compared to the numerical experience treatment. Participants' estimates for the probability of loss at the portfolio level are also qualitatively the same between the numerical and graphical experience treatments, and between Experiment 3 and Experiments 1 and 2: Participants either state an equal probability of loss or even a higher probability of loss for the low correlation condition, even though the true probability of loss is drastically reduced when the correlation is low (see Panel B of Table 10). Therefore, differences in the accuracy of beliefs are not a sufficient explanation for why participants diversify in the graphical experience treatment, but not in the numerical experience treatments. The results suggest that the graphical experience treatment alleviates correlation neglect as a result of a better understanding of diversification benefits, not just a better understanding of the distribution of returns.

6 Conclusion and Discussion

In this paper, we show experimentally that using an experience sampling procedure to inform investors about the correlation between the returns of two assets—as opposed to a description of correlation—alleviates the widely documented correlation neglect in asset allocation decisions. In particular, sampling return bars helps investors diversify more when the correlations between two assets are lower and diversification benefits are higher, in line with normative portfolio choice theory (Markowitz, 1952). Our findings are robust in two controlled laboratory experiments with varying levels of joint return distribution complexity and across different subsets of real investors in a field experiment.

Similar to the experiments in Ungeheuer and Weber (2019), our three experiments are designed to find out *how* presentation formats affect diversification decisions, not *why*. Thus, while we get cleanly identified evidence on the effect of presentation format on diversification choices, we cannot clearly disentangle whether presentation formats affect choice through beliefs or preferences or both. However, we have some indications about the channel, which can be used as a point of departure for future research.

First, more accurate beliefs about correlation after sampling might be part of the reason why sampling alleviates correlation neglect in our experiments. We test participants' perception of dependence via asking detailed questions on beliefs about the dependence between the two assets after each allocation decision. Beliefs about correlation significantly improve from description to sampling in Experiments 1 and 2, so that improved beliefs might be part of the explanation for why sampling alleviates correlation neglect. However, in Experiment 3 beliefs about correlation are, except for the question on downside co-movement, statistically the same in all presentation formats, despite significant differences in diversification choices between the description, numerical experience and graphical experience formats. Thus, accurate beliefs alone seem insufficient to explain our results. Maybe sampling of return bars additionally leads investors to have a stronger focus on diversification benefits (i.e., a stronger preference to diversify away large changes in portfolio value).

Second, we find the effect of presentation formats on diversification choices is not driven by a better understanding of risk at the portfolio level. Participants do not react to different correlations at all in their beliefs about the aggregate portfolio return distribution, despite large changes in the observed portfolio return distributions implied by their choices and correlation. Hence, we speculate that investors rather evaluate diversification benefits on a state-by-state basis (e.g., "Asset 2 usually increases when asset 1 decreases, so that holding more of asset 2 is beneficial"), which may lead to diversification effects without any explicit understanding of portfolio return distributions. It is also in line with Ungeheuer and Weber (2019), who find that participants diversify as if using a counting heuristic for up and down states in their perception of dependence ("Asset 2 usually increases when asset 1 decreases, so that holding more of asset 2 is beneficial.") instead of optimizing portfolio return distributions under observed correlations.

Assuming that the incorporation of diversification benefits into portfolio choice makes investors better off (Markowitz, 1952), our study has implications for regulators, financial institutions, investment advisors, and FinTech firms. Regulatory agencies should factor in the communication of diversification benefits, but typically focus on single assets only (e.g., they aim to make investment funds comparable with the help of standardized risk documents, like the key investor information documents in the European Union). Many banks, investment firms, and especially FinTech start up firms are using a portfolio-based allocation approach and offer decision-making tools on their websites and in their applications. Sampling from return distributions seems to help investors make optimal investment decisions and can be easily implemented in such decision-making tools. Of course, informing clients with the help of experience sampling may be a little more time consuming than simply providing a descriptive fact sheet. However, we provide evidence that this does not bother people. In Experiment 2, our online experiment with actual investors, we show that participants are as likely to complete the more time consuming sampling procedures as the quick, descriptive presentation procedure.

Taking a broader view, letting people experience relationships between different outcomes may improve diversification-like decisions in other areas, outside the financial domain. For example, farmers diversify over multiple plots of land, shipping companies diversify over multiple ships and travel routes, and it is common to argue that good friends are there for you when you need them the most (Desai, 2017). The fact that sampled dependence may lead to a better understanding of risks than just displaying probabilities should be tested in other fields. It might be particularly helpful when one of the variables can be controlled. As an illustration, the health care industry has problems communicating to patients the effects of controllable behavior on their health outcomes. A sampling procedure may be a helpful tool in this domain as well. Maybe, telling people that smoking cigarettes reduces their life expectancy by 10 years has a different effect than having them draw ages of death for smokers versus nonsmokers.

References

Bekaert, G., K. Hoyem, W.-y. Hu, and E. Ravina, 2017, "Who is internationally diversified? Evidence from the 401(k) plans of 296 firms," *Journal of Financial Economics*, 124(2), 86–112.

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

Benartzi, S., and R. H. Thaler, 2001, "Naive Diversification Strategies in Defined Contribution Saving Plans," *American Economic Review*, 91(1), 79–98.

——— , 2007, "Heuristics and Biases in Retirement Savings Behavior," *Journal of Economic Perspectives*, 21(3), 81–104.

Bradbury, M. A., T. Hens, and S. Zeisberger, 2015, "Improving Investment Decisions with Simulated Experience," *Review of Finance*, 19(3), 1019–1052.

Chen, D. L., M. Schonger, and C. Wickens, 2016, "oTree - an open-source platform for laboratory, online, and field experiments," *Journal of Behavioral and Experimental Finance*, (9), 88–97.

Cokely, E. T., M. Galesic, E. Schulz, and S. Ghazal, 2012, "Measuring Risk Literacy: The Berlin Numeracy Test," *Judgment and Decision Making*, 7(1), 25–47.

Desai, M., 2017, *The Wisdom of Finance: Discovering Humanity in the World of Risk and Return*. Houghton Mifflin Harcourt.

Eyster, E., and G. Weizsäcker, 2016, "Correlation Neglect in Portfolio Choice: Lab Evidence," Working Paper.

Fernandes, D., J. G. J. Lynch, and R. G. Netemeyer, 2014, "Financial Literacy, Financial Education, and Downstream Financial Behaviors," *Management Science*, 60(8), 1861–1883.

Fischbacher, U., 2007, "z-Tree: Zurich toolbox for ready-made economic experiments," *Experimental Economics*, 10(2), 171–178.

Fox, C. R., 2006, ""Decisions from experience" = sampling error + prospect theory: Reconsidering Hertwig, Barron, Weber & Erev (2004)," *Judgement and Decision Making*, 1(2), 159–161.

Greiner, B., 2003, "An Online Recruitement System for Economic Experiments," in *Forschung und wissenschaftliches Rechnen 2003*. No. 63, pp. 79–93.

Grinblatt, M., and M. Keloharju, 2001, "How Distance, Language, and Culture Influence Stockholdings and Trades," *Journal of Finance*, 56(3), 1053–1073.

Hau, R., T. J. Pleskac, J. Kiefer, and R. Hertwig, 2008, "The Description-Experience Gap in Risky Choice: The Role of Sample Size and Experienced Probabilities," *Journal of Behavioral Decision Making*, 21, 493–518.

Hertwig, R., G. Barron, E. U. Weber, and I. Erev, 2004, "Decisions From Experience and the Effect of Rare Events in Risky Choice," *Psychological Science*, 15(8), 534–9.

Kallir, I., and D. Sonsino, 2009, "The Neglect of Correlation in Allocation Decisions The Neglect of Correlation Allocation Decisions," *Southern Economic Journal*, 75(4), 1045–1066.

Kaufmann, C., M. Weber, and E. Haisley, 2013, "The Role of Experience Sampling and Graphical Displays on One's Investment Risk Appetite," *Management Science*, 59(2), 323–340.

Kaustia, M., and S. Knüpfer, 2008, "Do Investors Overweight Personal Experience? Evidence from IPO Subscriptions," *Journal of Finance*, 63(6), 2679–2702.

——— , 2012, "Peer performance and stock market entry," *Journal of Financial Economics*, 104(2), 321–338.

Knüpfer, S., E. Rantapuska, and M. Sarvimäki, 2017, "Formative Experiences and Portfolio Choice: Evidence from the Finnish Great Depression," *Journal of Finane*, 72(1), 133–166.

Kroll, Y., H. Levy, and A. Rapoport, 1988, "Experimental Tests of the Separation Theorem and the Capital Asset Pricing Model," *American Economic Review*, 78(3), 500–519.

Laudenbach, C., B. Loos, and J. Pirschel, 2017, "Recent Experiences and Risk Taking: Trading Responses to Changes in the Local Environment," Working Paper.

Lewis, K. K., 1999, "Trying to Explain Home Bias in Equities and Consumption," *Journal of Economic Literature*, 37(2), 571–608.

Lusardi, A., and O. S. Mitchell, 2014, "The Economic Importance of Financial Literacy: Theory and Evidence," *Journal of Economic Literature*, 52(1), 5–44.

Malmendier, U., and S. Nagel, 2011, "Depression Babies: Do Macroeconomic Experiences Affect Risk Taking?," *The Quarterly Journal of Economics*, 126(1), 373–416.

Markowitz, H. M., 1952, "Portfolio selection," *The Journal of Finance*, 7(1), 77–91.

Matthies, B., 2018, "Biases in the Perception of Covariance," Working Paper.

Reinholtz, N., P. M. Fernbach, and B. de Langhe, 2016, "Do People Understand the Benefit of Diversification?," Working Paper.

Strahilevitz, M. A., T. Odean, and B. M. Barber, 2011, "Once Burned, Twice Shy: How Naive Learning, Counterfactuals, and Regret Affect the Repurchase of Stocks Previously Sold," *Journal of Marketing Research*, 48(SPL), S102–S120.

Ungeheuer, M., and M. Weber, 2019, "The Perception of Dependence, Investment Decisions, and Stock Returns," *Journal of Finance forthcoming*.

Wunderlich, K., M. Symmonds, P. Bossaerts, and R. J. Dolan, 2011, "Hedging Your Bets by Learning Reward Correlations in the Human Brain," *Neuron*, 71(6), 1141–1152.

Figure 1: Experiments 1 to 3: Feasible Set

For each of the correlation conditions, this figure displays the combinations of expected portfolio risk (standard deviation of return) and portfolio return that are attainable with portfolio weights between 0 and 1. The low and high correlation conditions exhibit correlations between the two assets of -0.6 and 0.6, respectively.

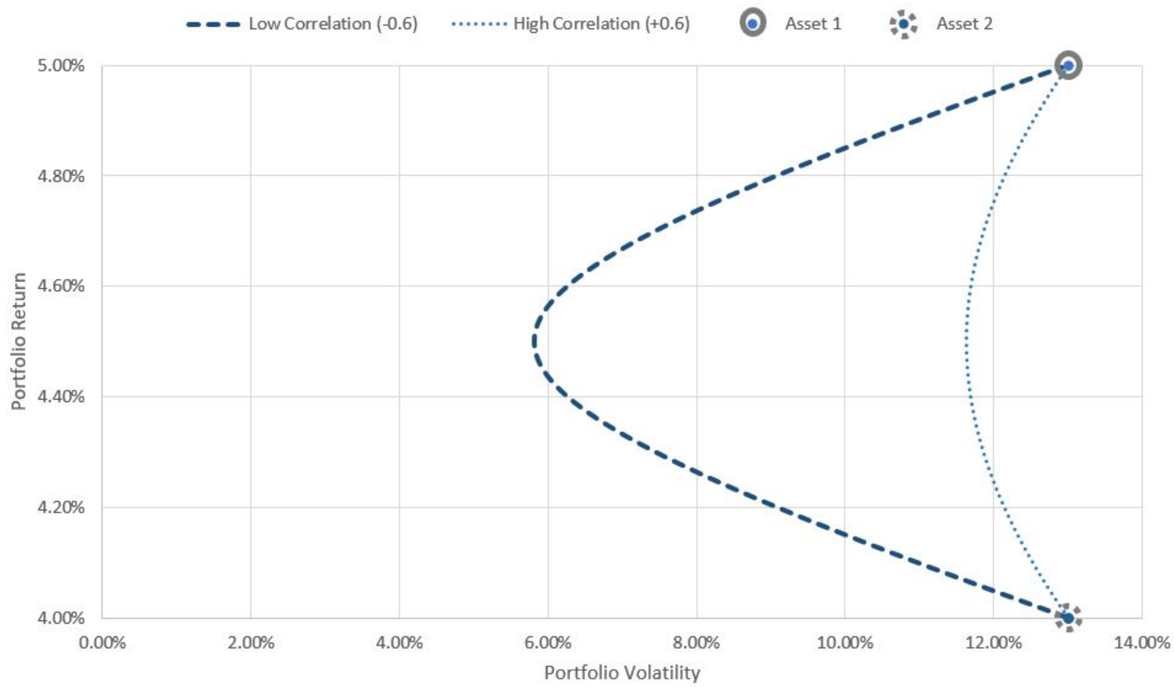


Figure 2: Experiment 1 to 3: CRRA-Optimal Investment in Diversification Asset 2

For each of the conditions, this figure displays the investment in asset 2 as a percentage of the total portfolio that maximizes the expected CRRA-utility at levels of relative risk aversion between 0.5 and 10. Conditions 1 and 2 exhibit correlations between the two assets of -0.6 and 0.6, respectively. The investment is restricted to be in the closed interval between 0 and 1 and we assume that the remaining funds are invested in asset 1.

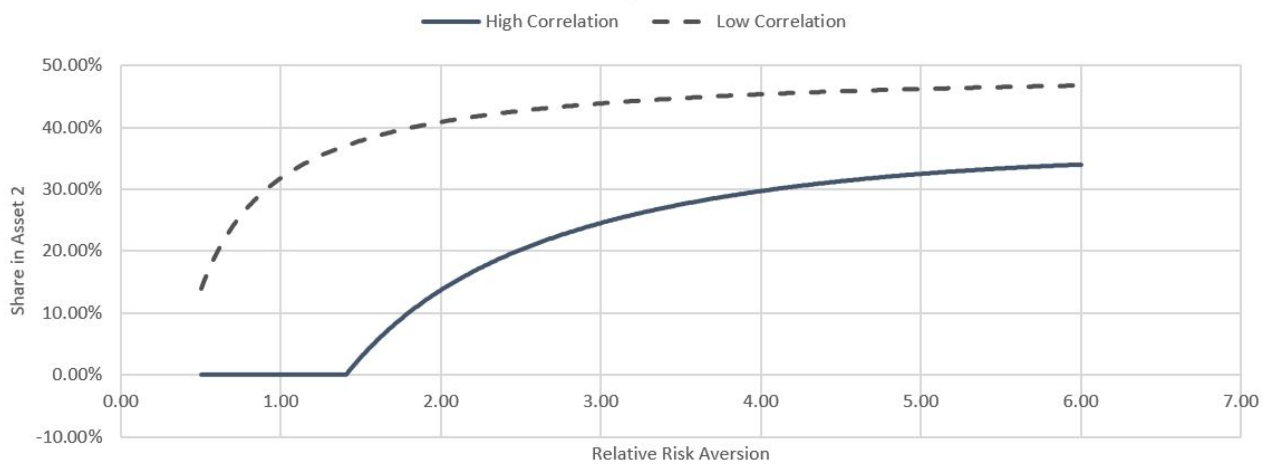


Figure 3: Illustration of Presentation Formats

These exhibits illustrate the information shown to participants in Experiments 1, 2, and 3. Panel A shows the information presented in the description treatment for low (left-hand side) and high (right-hand side) correlation conditions in Experiments 1 and 2. Panel B depicts two example pictures from the numerical experience treatment (left-hand side) and the graphical experience treatment (right-hand side) respectively. Panel C shows how the joint normal distribution is described in Experiment 3 for the low correlation condition. In Experiment 3, we included a reading example, saying "In 10 out of 100 cases asset 1 has an annual return between -5% and 5%, while asset 2 at the same time has an annual return between 5% and 15%." Note that treatments (presentation formats) were held constant within participants, but every participant faced both conditions (low and high correlation); the order of conditions was counterbalanced. Returns are displayed in green (red) when positive (negative). The labels are in German. Translations: "Anlage X (durchschnittliche Rendite pro Jahr = y%)" means "Asset X (average return per year = y%)". "...zu erwarten in ... von 100 Fällen" means "...to be expected in ... of 100 cases". "Rendite Simulation für Anlage 1 & 2" means 'Return-Simulation for assets 1 & 2".

Panel A: Description Treatment in Experiments 1 & 2

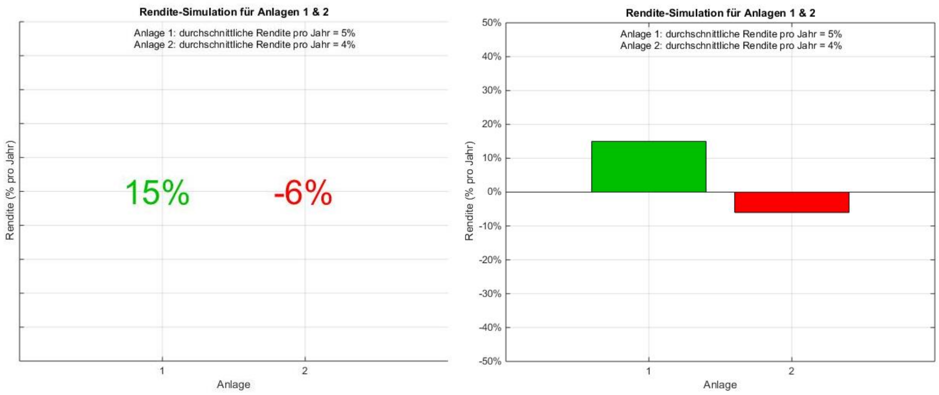
Anlage 1: durchschnittliche Rendite pro Jahr = 5%
Anlage 2: durchschnittliche Rendite pro Jahr = 4%

Rendite (% pro Jahr) Anlage 1	Anlage 2	zu erwarten in ... von 100 Fällen
-25%	-26%	1
-25%	34%	4
-5%	-6%	9
-5%	14%	36
15%	-6%	36
15%	14%	9
35%	-26%	4
35%	34%	1

Anlage 1: durchschnittliche Rendite pro Jahr = 5%
Anlage 2: durchschnittliche Rendite pro Jahr = 4%

Rendite (% pro Jahr) Anlage 1	Anlage 2	zu erwarten in ... von 100 Fällen
-25%	-26%	4
-25%	34%	1
-5%	-6%	36
-5%	14%	9
15%	-6%	9
15%	14%	36
35%	-26%	1
35%	34%	4

Panel B: Sampling Treatments in Experiments 1 to 3



Panel C: Description Treatment in Experiment 3

Anlage 1: durchschnittliche Rendite pro Jahr = 5%

Anlage 2: durchschnittliche Rendite pro Jahr = 4%

Rendite (% pro Jahr) Anlage 1	**Anlage 2**	**zu erwarten in ... von 100 Fällen**
weniger als -5%	weniger als -5%	1
	zwischen -5% und 5%	3
	zwischen 5% und 15%	7
	mehr als 15%	10
zwischen -5% und 5%	weniger als -5%	4
	zwischen -5% und 5%	8
	zwischen 5% und 15%	10
	mehr als 15%	6
zwischen 5% und 15%	weniger als -5%	8
	zwischen -5% und 5%	10
	zwischen 5% und 15%	7
	mehr als 15%	3
mehr als 15%	weniger als -5%	12
	zwischen -5% und 5%	7
	zwischen 5% und 15%	3
	mehr als 15%	1

Lesebeispiel:
In 10 von 100 Fällen hat Anlage 1 eine Rendite zwischen -5% und 5% pro Jahr und Anlage 2 **gleichzeitig** eine Rendite zwischen 5% und 15% pro Jahr.

Figure 4: Experiment 1: Realized Correlation by Presentation Format

This figure displays the frequency distribution of realized correlations for each of the treatments in Experiment 1. Participants in the description treatment always viewed a representative picture of the underlying distribution and hence all realize a correlation of 0.6 for the first and -0.6 for second condition or vice versa. Participants in the numerical and graphical experience treatments view 60 return-pairs for each decision. These return-pairs are drawn from a representative distribution of 100 return-pairs without replacement, which results in small sampling errors.

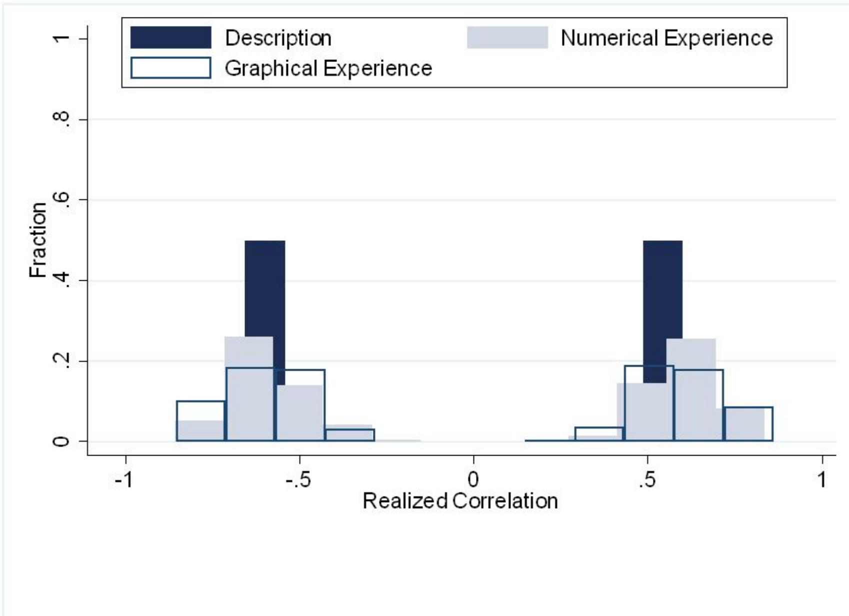


Figure 5: Experiment 2: Cross-Sectional Variation Diversification Choice

These graphs show the average investment in asset 2 by correlation (low and high) for subsamples in Experiment 2. For each pair of bars, the blue, left-hand side bar is the average investment in asset 2 in the low correlation treatment. The subgroups are displayed below each pair of bars, with the number of observations in parentheses and 1/2/3 asterisks indicating statistical significance of the difference between low and high correlation derived from random effect regressions at the 10%/5%/1% level. Table B1 contains variable descriptions.

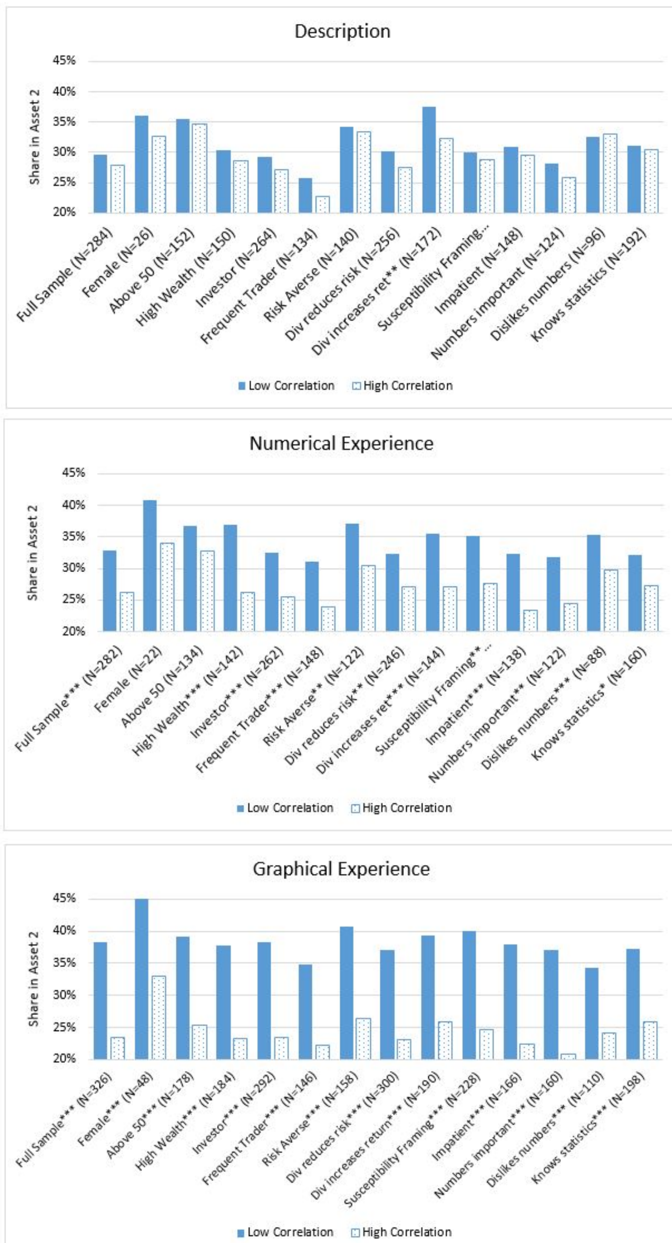
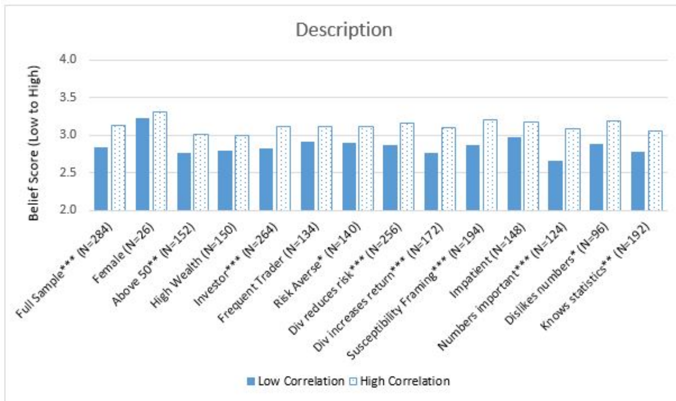
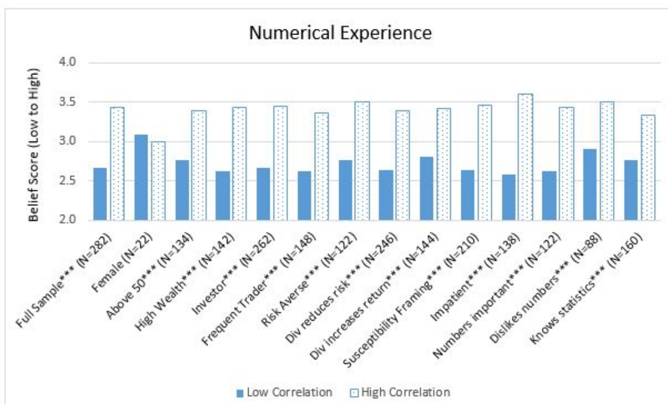


Figure 6: Experiment 2: Cross-Sectional Variation Dependence Beliefs

These graphs show the average belief about overall dependence by correlation (low and high) for subsamples in Experiment 2. Beliefs about dependence are based on the first dependence question reported in Table 8. Labelling is done as in Figure 5.





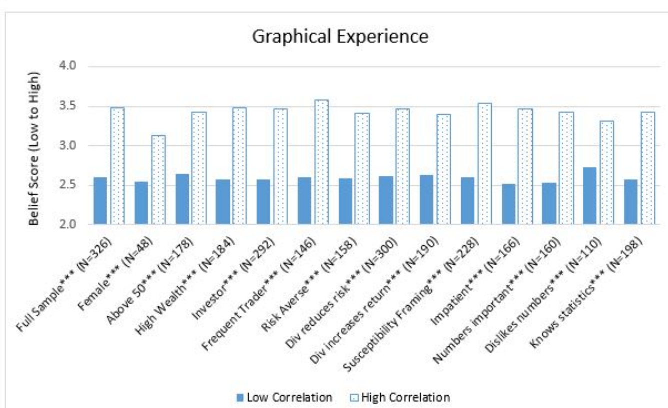


Figure 7: Realized Correlation and Comovement across Experiments

For eacht of the experiments, we plot realized correlations against the fraction of comovement (same-signed return pairs) for all participants in the experience treatments.

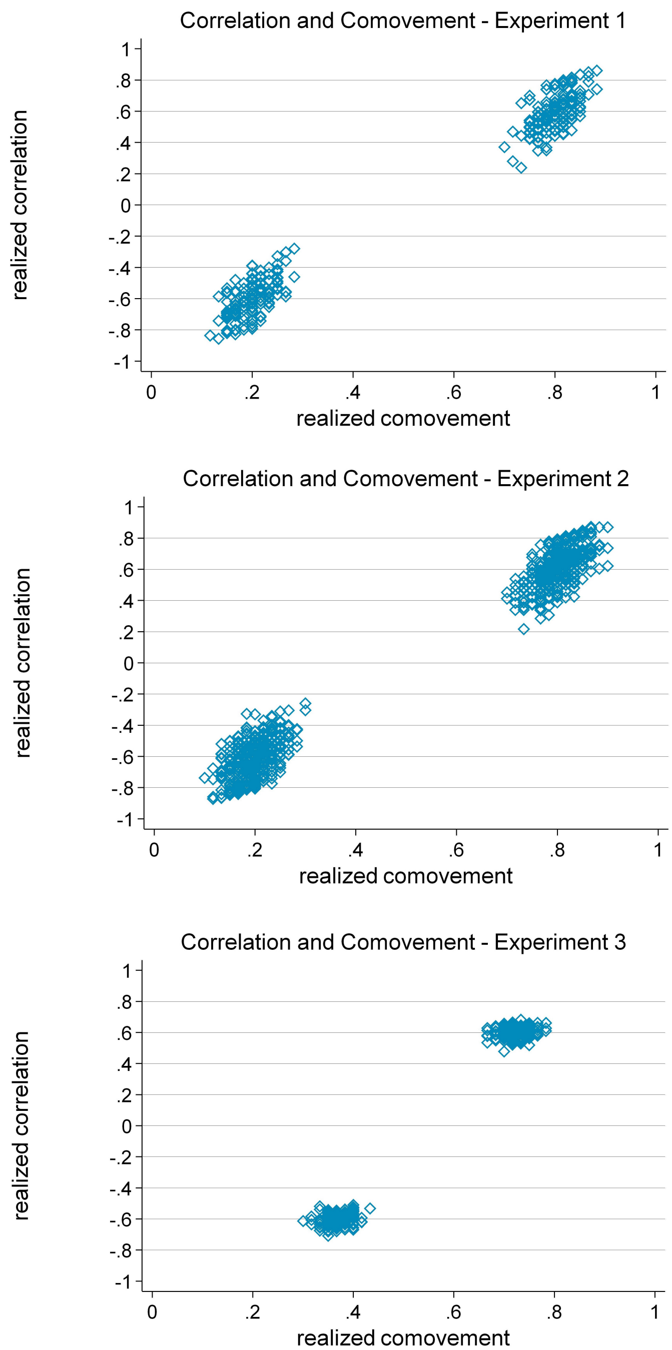


Table 1: Experiment 1: Correlation Conditions

These tables show the joint distributions for asset 1 (returns in first row) and asset 2 (returns in first column) for the two different correlation conditions. Marginal distributions are kept constant across treatments and experiments. Means are 5.0% for asset 1 and 4.0% for asset 2. Standard-deviations are 13.0% for both assets. Both conditions are shown to every participant in random order (counterbalanced within-subject design). The presentation format varies between-subjects.

Low correlation condition: Pearson-Correlation of −0.6

return	−25%	−5%	15%	35%	sum
−26%	1%	0%	0%	4%	5%
−6%	0%	9%	36%	0%	45%
14%	0%	36%	9%	0%	45%
34%	4%	0%	0%	1%	5%
sum	5%	45%	45%	5%	100%

High correlation condition: Pearson-Correlation of +0.6

return	−25%	−5%	15%	35%	sum
−26%	4%	0%	0%	1%	5%
−6%	0%	36%	9%	0%	45%
14%	0%	9%	36%	0%	45%
34%	1%	0%	0%	4%	5%
sum	5%	45%	45%	5%	100%

Table 2: Summary Statistics

This table reports summary statistics (means and standard deviations) for participants in Experiments 1 (Panel A) and 2 (Panel B) by treatment. Numbers in parentheses indicate the range of possible values. *Financial literacy* is measured as the number of correctly answered questions in the test proposed by Fernandes, Lynch, and Netemeyer (2014). *Numeracy* is measured as the number of correctly answered questions in the test proposed by Cokely, Galesic, Schulz, and Ghazal (2012). Table B1 contains variable descriptions.

Panel A: Summary Statistics Experiment 1

	All N=286		Description N=98		Exp. Numerical N=96		Exp. Graphical N=92	
	Mean	Std. Dev	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Age	22.38	3.01	22.36	3.05	22.57	3.09	22.21	2.91
Fraction Male	0.48	0.50	0.50	0.50	0.46	0.50	0.47	0.50
Owns Equity	0.23	0.42	0.18	0.39	0.25	0.44	0.25	0.44
Interested in Financial Markets	0.65	0.48	0.63	0.48	0.68	0.47	0.64	0.48
Willingness to Take Risks (1-5)	2.63	1.05	2.61	1.05	2.64	1.08	2.64	1.03
Has Taken Statistics Course	0.70	0.46	0.67	0.47	0.67	0.47	0.77	0.42
Self-Assessed Stats Knowledge (1-4)	2.37	0.98	2.43	1.01	2.42	1.00	2.26	0.92
Financial Literacy (0-12)	6.99	2.56	7.06	2.56	6.95	2.61	6.95	2.53
Numeracy (0-4)	1.29	1.29	1.30	1.33	1.33	1.31	1.23	1.23

Panel B: Summary Statistics Experiment 2

	All N=446		Des. N=142		Exp. Num. N=141		Exp. Graph. N=163	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Age	51.03	14.36	50.07	15.14	51.11	14.81	51.79	13.26
Fraction Male	0.89	0.31	0.91	0.29	0.92	0.27	0.85	0.36
Owns Equity	0.92	0.28	0.93	0.26	0.93	0.26	0.90	0.31
Interested in Financial Markets	0.98	0.13	0.98	0.14	0.99	0.08	0.98	0.16
Willingness to Take Risks (1-5)	3.46	0.92	3.47	0.85	3.55	0.94	3.37	0.95
Self-Assessed Stats Knowledge (1-5)	2.87	1.09	2.96	1.07	2.81	1.16	2.83	1.06
Financial Literacy (0-2)	1.88	0.37	1.91	0.31	1.84	0.46	1.90	0.34
Div. decreases risk	0.90	0.30	0.90	0.30	0.87	0.34	0.92	0.27
Div. increases return	0.26	0.44	0.23	0.42	0.35	0.48	0.22	0.42
Self-Assessed Patience (0-10)	5.98	2.37	5.88	2.48	5.97	2.41	6.07	2.25
Trading Frequency	Median: 4-12 months, p10: 1-4 weeks, p90: >1 year							
Wealth excl. RE	Median: >100,000,€ p10: 5,000-20,000,€ p90: >100,000€							

Panel C: Summary Statistics Experiment 3								
	All N=303		Des. N=110		Exp. Num. N=96		Exp. Graph. N=92	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Age	22.48	4.97	23.22	6.49	21.54	2.85	22.61	4.57
Fraction Male	0.51	0.50	0.51	0.50	0.57	0.50	0.46	0.50
Owns Equity	0.26	0.44	0.24	0.43	0.33	0.47	0.20	0.40
Interested in Financial Markets	0.63	0.48	0.65	0.48	0.64	0.48	0.62	0.49
Willingness to Take Risks (1-5)	2.87	1.10	2.93	1.15	2.87	1.12	2.82	1.04
Has Taken Statistics Course	0.61	0.49	0.63	0.49	0.58	0.50	0.63	0.49
Self-Assessed Stats Knowledge (1-4)	2.52	0.98	2.51	0.93	2.44	1.11	2.62	0.89
Financial Literacy (0-12)	7.02	2.36	7.13	2.26	7.15	2.25	6.74	2.57
Numeracy (0-4)	1.14	1.29	1.07	1.25	1.27	1.33	1.06	1.28

Table 3: Experiment 1: Allocation into Diversification Asset 2

Panel A shows the average allocation to the diversification asset 2 in % by condition and treatment. Panel B shows the difference-in-differences between conditions by treatments.

Panel A: Descriptive Statistics on Allocation					
	Low Correlation	High Correlation	Difference	t-stat	Average
Description	31.02%	33.08%	2.06%	0.88	32.05%
Numerical Experience	36.56%	29.19%	-7.37%**	-2.54	32.88%
Graphical Experience	42.93%	32.31%	-10.62%***	-4.05	37.62%

Panel B: Differences between Treatments				
	Diff in Diff	t-stat	Diff in Average	t-stat
Numerical Experience - Description	-9.43%**	-2.54	0.83%	0.36
Graphical Experience - Description	-12.68%***	-3.62	5.56%**	2.49
Graphical Experience - Numerical Experience	-3.25%	-0.83	4.74%**	2.11

Table 4: Experiment 1: Asset Allocation Regressions I

$Share_2$ is the investment in asset 2 (as a portfolio weight between 0 and 1). Asset 2 has a lower return and the same marginal distribution, compared to asset 1; it should thus only be interesting because of its diversification potential. Table B1 contains variable descriptions. In Specification (2), we exclude participants investing more than 50% in asset 2. In Specification (3), we look at participants' first decision only and thus is purely between-subjects. In Specification (4), we test for learning effects. We run random effects regressions (except for regression (3)) to take account of participant-specific effects. *t*-stats are reported in parentheses. 1/2/3 astericks denote significance at the 10%/5%/1%-level.

Panel A: Baseline Regressions

	Share_2 *All*	Share_2 *$Share_2$ <=0.5*	Share_2 *First Decision*	Share_2 *All*
Numerical x High Corr.	-0.0943***	-0.0782***	-0.0911*	-0.0945***
	(-2.56)	(-2.75)	(-1.69)	(-2.56)
Graphical x High Corr.	-0.1268***	-0.0838***	-0.1447***	-0.1269***
	(-3.41)	(-2.83)	(-2.66)	(-3.40)
Numerical Experience	0.0554*	0.0473*	0.0432	0.0552*
	(1.91)	(1.94)	(1.15)	(1.90)
Graphical Experience	0.1190***	0.0869***	0.1165***	0.1189***
	(4.06)	(3.40)	(3.09)	(4.04)
High Correlation	0.0206	0.0073	0.0340	0.0292
	(0.80)	(0.37)	(0.90)	(0.92)
Learning				-0.0170
				(-0.46)
Second Decision				0.0066
				(0.27)
Constant	0.3102***	0.2708***	0.3118***	0.3071***
	(15.19)	(15.89)	(12.00)	(13.16)
Random Effects	YES	YES	NO	YES
No. obs.	572	497	286	572

Table 4 cont.

Regression results in this table are analogous to Table 4. *Last Corr High* is a dummy equal to 1 if participants' last draw pictures a high correlation. *First Corr High* is a dummy equal to 1 if participants' last draw pictures a high correlation. *Last Return Asset 1* and Last Return Asset 2 are the participants' last returns sampled for asset 1 and 2 respectively. *First Return Asset 1* and First Return Asset 2 are the participants' first returns sampled for asset 1 and 2 respectively. Specifications (1) to (4) analyze the effect of experienced return histories and thus only include participants with variation in observed returns, i.e. the description treatment is excluded. Specification (5) only includes participants with a low sampling error, namely participants who sampled a correlation between -0.55 and -0.65 in the low and between 0.55 and 0.65 in the high correlation condition. We run random effects regressions to take account of participant-specific effects. *t*-stats are reported in parentheses. 1/2/3 asterisks denote significance at the 10%/5%/1%-level.

Panel B: Recency Effects and Sampling Error					
	$Share_2$ *All*	$Share_2$ *Last Corr*	$Share_2$ *First Corr*	$Share_2$ *Last/First Ret*	$Share_2$ *Real. Corr. +/- 5pp*
Last Corr High		-0.0184			
		(-0.67)			
First Corr High			-0.0421*		
			(-1.67)		
Last Return Asset 1				0.0956	
				(1.21)	
Last Return Asset 2				-0.0574	
				(-0.73)	
First Return Asset 1				-0.0403	
				(-0.49)	
First Return Asset 2				0.0352	
				(0.43)	
Numerical x High Corr.					-0.1270**
					(-2.43)
Graphical x High Corr.	-0.0325	-0.0329	-0.0252	-0.0330	-0.1060**
	(-0.83)	(-0.84)	(-0.64)	(-0.83)	(-2.01)
Numerical Experience					0.0734*
					(1.74)
Graphical Experience	0.0636**	0.0640**	0.0600**	0.0626**	0.1321***
	(2.14)	(2.15)	(2.01)	(2.09)	(3.26)
High Correlation	-0.0737***	-0.0617*	-0.0535*	-0.0731***	0.0206
	(-2.69)	(-1.88)	(-1.79)	(-2.62)	(0.90)
Constant	0.3656***	0.3689***	0.3766***	0.3634***	0.3102***
	(17.55)	(17.24)	(17.28)	(16.36)	(15.87)
Random Effects	YES	YES	YES	YES	YES
No. obs.	376	376	376	376	311

Table 5: Experiment 1: Attention Paid to Presentation Formats

Panel A shows the average total time spent with the information about asset returns by treatment. This information is shown by condition (high vs. low correlation) as well as decision round. Panel B shows the allocation to the diversification asset 2 for participants who spent above (below) median time to view the information about the asset returns. Median splits were conducted for each treatment×condition separately. 1/2/3 asterisks denote significance at the 10%/5%/1%-level.

Panel A: Time in Seconds by Presentation Format

Time by Condition	Low Correlation	High Correlation	Difference	t-stat
Description	75.28	74.54	-0.73	-0.08
Numerical Experience	111.04	108.40	-2.64	-0.30
Graphical Experience	109.22	102.51	-6.71	-0.71

Time by Decision Round	Round 1	Round 2	Difference	t-stat
Description	67.85	81.97	14.13*	1.68
Numerical Experience	123.73	95.71	-28.01***	-3.32
Graphical Experience	122.27	89.47	-32.80***	-3.60

Panel B: Attention Paid and Asset Allocation

	Low Correlation	High Correlation	Difference	t-stat
Total Time < Median				
Description	30.31%	34.02%	3.71%	0.92
Numerical Experience	37.15%	28.16%	-8.99%**	-2.03
Graphical Experience	42.73%	30.56%	-12.16%***	-2.96
Total Time > Median				
Description	31.79%	32.10%	0.41%	0.10
Numerical Experience	36.00%	30.26%	-5.74%	-1.31
Graphical Experience	43.11%	34.21%	-8.90%**	-2.26

Table 6: Experiment 1: Perceptions of Dependence and Risk

Panel A of the table shows the frequency of each answer-category for our question on overall beliefs about dependence. Boxes around numbers indicate correct answers. All answers are shown by treatment and condition. Below the first panel, you will find the mean category for each treatment and condition and differences between these means by treatment. Panel B shows participants' average estimates of the loss probability of their portfolio, which was the answer to the question "in how many cases their final wealth will fall below the invested amount", as well as the true probability of loss for their portfolio. t-stats are reported in parentheses. 1/2/3 asterisks denote significance at the 10%/5%/1%-level.

Panel A: Correlation Perception (Overall Dependence): Asset 1 and 2 move...

	Description		Numerical Experience		Graphical Experience	
	Low Corr	High Corr	Low Corr	High Corr	Low Corr	High Corr
in opposite directions 1	[2]	1	[4]	2	[5]	1
2	[36]	25	[48]	3	[57]	9
3	44	51	37	23	23	25
4	16	[19]	7	[62]	6	[56]
together 5	0	[2]	0	[6]	1	[1]
mean	2.76	2.96	2.49	3.70	2.36	3.51
- low correlation	-	0.20^{*}	-	1.21^{***}	-	1.15^{***}
		(1.90)		(11.76)		(10.64)
chi^2-test of differences						
-Diff in Corr in Description		-	-	1.00^{***}	-	0.95^{***}
-Diff in Corr in Numerical Experience	-	-	-	-		-0.06

Panel B: Estimation of expected "loss cases" and true values

	Low Correlation	High Correlation	Difference	t-stat
Average Estimate				
Description	32.77%	33.23%	0.47%	(0.18)
Numerical Experience	32.46%	27.49%	$-4.97\%^{*}$	-1.95
Graphical Experience	27.84%	28.33%	0.49%	0.21
Average True Value				
Description	27.39%	44.60%	$17.21\%^{***}$	9.31
Numerical Experience	22.73%	45.28%	$22.55\%^{***}$	12.09
Graphical Experience	20.02%	44.31%	$24.29\%^{***}$	14.04

Table 7: Experiment 2: Allocation into Diversification Asset 2

Panel A shows the average allocation into the diversification asset 2 in % by condition and treatment. Panel B shows the difference-in-differences between conditions by treatments.

Panel A: Descriptive Statistics on Allocation

	Low Correlation	High Correlation	Difference	t-stat	Average
Description	29.66%	27.78%	-1.88%	-0.62	28.72%
Numerical Experience	32.87%	26.21%	-6.66%**	-2.28	29.54%
Graphical Experience	38.33%	23.46%	-14.87%***	-5.44	30.90%

Panel B: Differences between Treatments

	Diff in Diff	t-stat	Diff in Average	t-stat
Numerical Experience - Description	-4.78%*	-1.67	0.82%	0.38
Graphical Experience - Description	-12.99%***	-4.41	2.18%	1.05
Graphical Experience - Numerical Experience	-8.21%***	-2.74	1.36%	0.66

Table 8: Experiment 2: Perceptions of Dependence and Risk

Panel A shows the frequency of each answer-category for our question on overall beliefs about dependence. Boxes around numbers indicate correct answers. All answers are shown by treatment and condition. Below the first panel, you will find the mean category for each treatment and condition and differences between these means by treatment. Panel B shows participants' average estimates of the loss probability of their portfolio, which was the answer to the question "in how many cases their final wealth will fall below the invested amount", as well as the true probability of loss for their portfolio. t-stats are reported in parentheses. 1/2/3 asterisks denote significance at the 10%/5%/1%-level.

Panel A: Correlation Perception (Overall Dependence): Asset 1 and 2 move...

	Description		Numerical Experience		Graphical Experience	
	Low Corr	High Corr	Low Corr	High Corr	Low Corr	High Corr
in opposite directions 1	[4]	2	[8]	4	[9]	1
2	[41]	30	[52]	9	[65]	12
3	75	69	63	57	73	62
4	18	[30]	14	[63]	14	[85]
together 5	4	[11]	4	[8]	2	[3]
mean	2.83	3.12	2.68	3.44	2.60	3.47
- low correlation	-	0.29***	-	0.76***	-	0.87***
		(2.91)		(7.77)		(10.74)
chi^2-test of differences						
-Diff in Corr in Description		-	-	0.47***	-	0.58***
				(3.56)		(4.75)
-Diff in Corr in Numerical Experience	-	-	-	-		0.11
						(0.82)

Panel B: Estimation of expected "loss cases" and true values

	Low Correlation	High Correlation	Difference	t-stat
Average Estimate				
Description	27.11%	27.39%	0.28%	0.12
Numerical Experience	28.78%	28.11%	-0.67%	-0.31
Graphical Experience	23.41%	21.96%	-1.45%	-0.87
Average True Value				
Description	29.52%	46.27%	16.75%***	11.67
Numerical Experience	28.67%	45.88%	17.21%***	11.75
Graphical Experience	27.40%	46.25%	18.85%***	13.75

Table 9: Experiment 3: Allocation into Diversification Asset 2

Panel A shows the average allocation into the diversification asset 2 in % by condition and treatment. Panel B shows the difference in differences between conditions by treatments.

Panel A: Descriptive Statistics on Allocation

	Low Correlation	High Correlation	Difference	t-stat	Average
Description	44.86%	43.24%	-1.62%	-0.55	44.05%
Numerical Experience	38.45%	37.81%	-0.64%	-0.27	38.13%
Graphical Experience	45.31%	37.25%	-8.06%***	-3.26	41.28%

Panel B: Differences between Treatments

	Diff in Diff	t-stat	Diff in Average	t-stat
Numerical Experience - Description	0.98%	0.26	-5.92%**	-2.46
Graphical Experience - Description	-6.44%*	-1.73	-2.77%	-1.21
Graphical Experience - Numerical Experience	-7.42%**	-2.17	3.15%	1.33

Table 10: Experiment 3: Perceptions of Dependence and Risk

Panel A shows the frequency of each answer-category for our question on overall beliefs about dependence. All answers are shown by treatment and condition. Boxes around numbers indicate correct answers. Below the first panel, you will find the mean category for each treatment and condition and differences between these means by treatment. Panel B This shows participants' average estimates of the loss probability of their portfolio, which was the answer to the question "in how many cases their final wealth will fall below the invested amount", as well as the true probability of loss for their portfolio. *t*-stats are reported in parentheses. 1/2/3 asterisks denote significance at the 10%/5%/1%-level.

Panel A: Correlation Perception (Overall Dependence): Asset 1 and 2 move...

	Description		Numerical Experience		Graphical Experience	
	Low Corr	High Corr	Low Corr	High Corr	Low Corr	High Corr
Overall Dependence: Asset 1 and 2 move...						
in opposite directions 1	6	2	2	1	3	1
2	60	17	60	10	46	9
3	19	18	22	28	34	29
4	15	51	8	55	8	52
together 5	2	12	1	1	0	1
don't know	8	10	6	4	3	2
mean	2.48	3.54	2.42	3.47	2.52	3.47
- low correlation	-	1.06^{***}	-	1.05^{***}	-	0.95^{***}
		(8.07)		(9.84)		(8.94)
chi^2-test of differences						
-Diff in Corr in Description		-	-	-0.01	-	-0.11
-Diff in Corr in Numerical Experience	-	-	-	-		-0.10

Panel B: Estimation of expected "loss cases" and true values

	Low Correlation	High Correlation	Difference	*t*-stat
Average Estimate				
Description	22.20%	25.22%	3.02%	1.27
Numerical Experience	35.49%	30.37%	-5.12%**	-2.37
Graphical Experience	32.82%	29.41%	-3.40%	-1.55
Average True Value				
Description	26.56%	35.13%	8.57%***	20.80
Numerical Experience	26.04%	34.51%	8.47%***	15.66
Graphical Experience	25.79%	35.04%	9.25%***	17.41

Internet Appendix for
How to Alleviate Correlation Neglect

Abstract

The Internet Appendix consists of five sections. Appendices A and B contain additional figures and tables, which are referred to in the main paper. In Appendix C, we discuss results of an additional presentation format, namely a graphical description. Appendix D contains the instructions and questions from Experiments 1-3.

A Additional Figures

Figure A1: Experimental Flow

This figure gives an overview of the experimental setup.

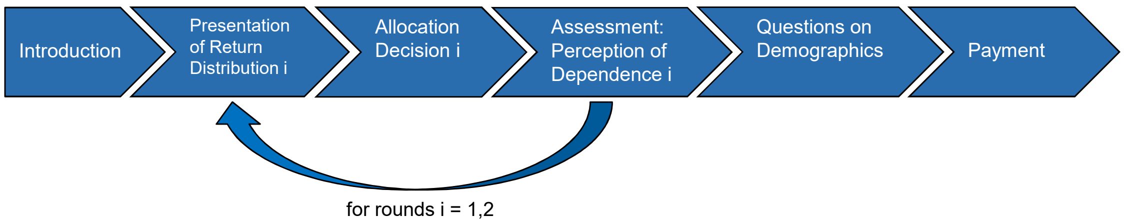
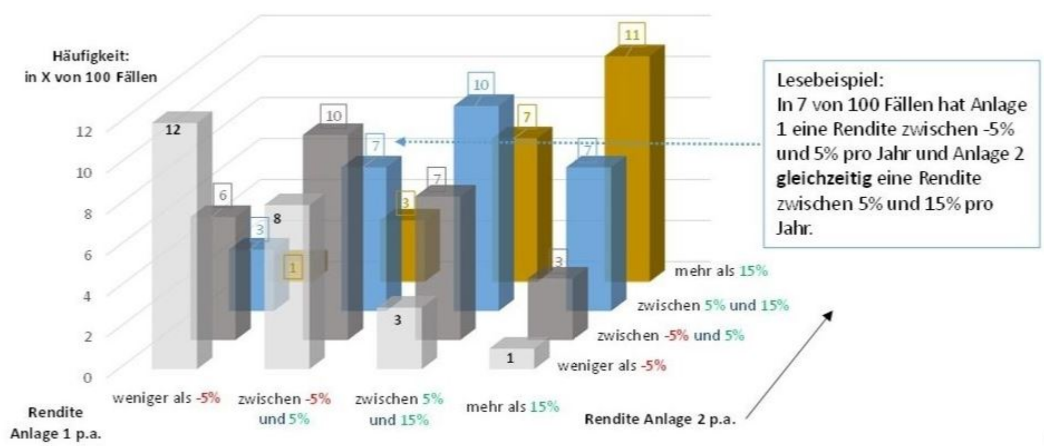


Figure A2: Experiment 3: Graphial Description Treatment

This figure shows how the joint normal distribution is presented in the graphical description treatment in Experiment 3. The high (low) correlation condition is displayed on the left (right). We included a reading example, saying "In 10 out of 100 cases asset 1 has an annual return between -5% and 5%, while asset 2 at the same time has an annual return between 5% and 15%". The labels are in German. Translations: "Anlage X (durchschnittliche Rendite pro Jahr = y%)" means "Asset X (average return per year = y%)". "zu erwarten in ... von 100 Fällen" means "to be expected in ... of 100 cases". "Rendite Simulation für Anlage 1 & 2" means "Return-Simulation for Assets 1 & 2".



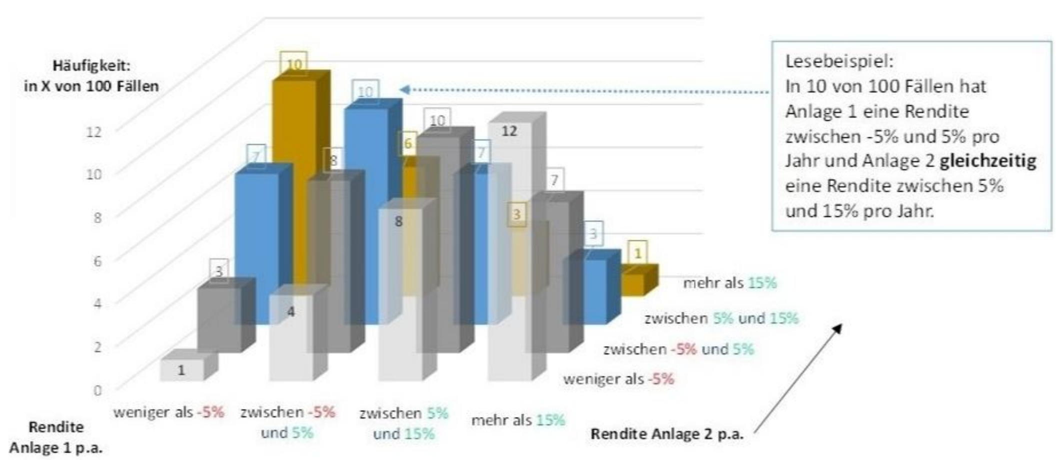
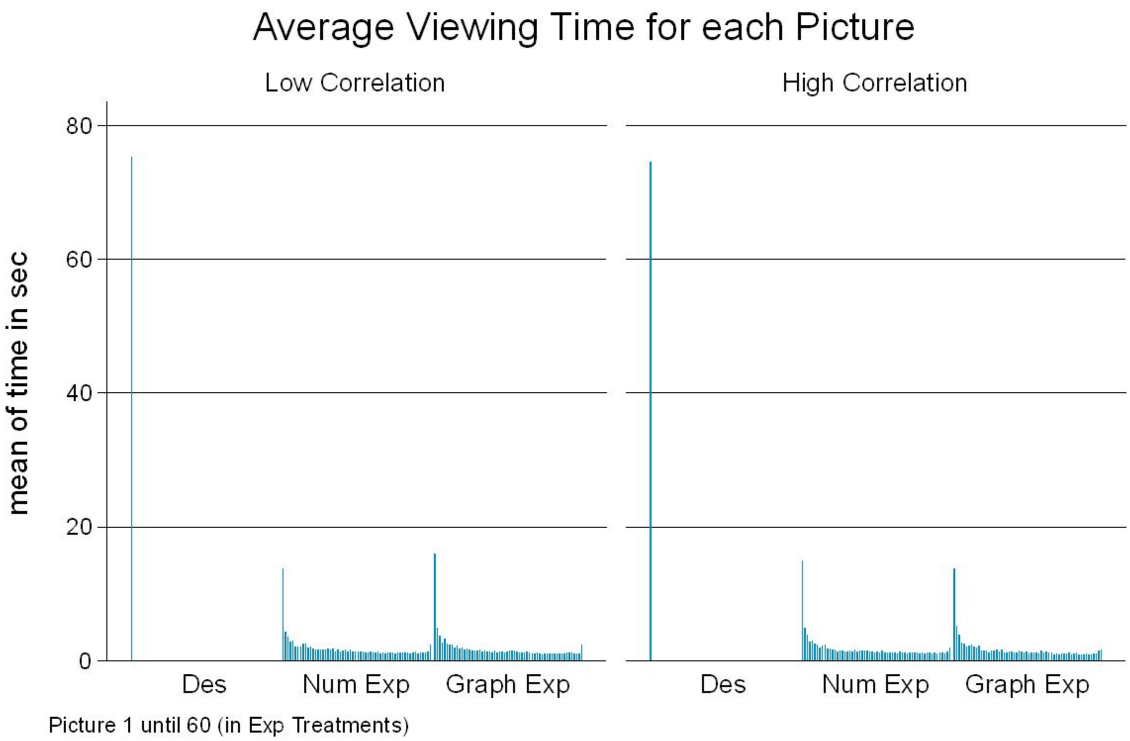


Figure A3: Experiment 1: Attention Paid to Presentation Formats

For each of the treatments and conditions, this figure displays the number of seconds participants looked on average at each of the pictures. There was one picture in the description treatment and 60 pictures of return-pairs in the numerical experience and graphical experience treatments, respectively. The first bar reflects the time spent with the first picture, the second one the time spent with the second picture and so on. Results are shown for the first round only.



B Additional Tables

Table B1: Variable Descriptions

Variable	Description
Age	Age of the participant.
Confidence	"How confident are you about your investment decision?" (Seven radio buttons from "not confident at all" to "very confident".)
Description	Dummy equal to 1 if a participant was randomly assigned to this treatment.
Div. decreases risks	Dummy equal to 1 if a participant is able to correctly state that diversification decreases risk. For the exact question, see Experimental Description in Appendix E.
Div. increases return	Dummy equal to 1 if a participant is able to correctly state that diversification does not increase return expectations. For the exact question, see Experimental Description in Appendix E.
Financial Literacy	Experiment 1 and 3: Financial Literacy Score between 0 and 12: The number of correct answers to twelve financial literacy questions from Fernandes, Lynch, and Netemeyer (2014). Item (8) from the original test was left out since the experiments were conducted in Germany (it is a question related to 401(k) plans and therefore specific to the US setting). For the exact question, see Experimental Description in Appendix E.)
Financial Literacy	Experiment 2: Financial Literacy Score between 0 and 2: The number of correct answers to two financial literacy questions taken from Fernandes, Lynch, and Netemeyer (2014). For the exact question, see Experimental Description in Appendix E.
First Corr High	Dummy equal to one if a participant's first draw pictures a high correlation.
First Return Asset 1	First return sampled for asset 1.

Variable	Description
First Return Asset 2	First return sampled for asset 2.
Frequency of Comovement	"Given that asset 1's price increases, I expect asset 2's price to increase in ... out of 100 cases." (Any numerical answer from 0 to 100 was allowed.)
Graphical Experience	Dummy equal to 1 if a participant was randomly assigned to this treatment.
Graphical x High Corr.	Interaction term equal to 1 if a participant is in the graphical experience treatment and faces the high correlation condition.
Has taken Statistics Course	Dummy equal to 1 if a participant answer to the following question is yes: "Have you attended a university statistics course?"
High Correlation	Dummy equal to 1 for the round where participants face the positive correlation condition..
Interested in Financial Markets	Dummy equal to 1 if a participant answer to the following question is yes: "Are you generally interested in stock or financial markets?"
Last Corr High	Dummy equal to one if a participant's last draw pictures a high correlation.
Last Return Asset 1	Last return sampled for asset 1.
Last Return Asset 2	Last return sampled for asset 2.
Learning	Interaction term that is equal to 1 if a participant faces a high correlation and is in the second round of the experiment (second decision).
Loss Probability - Estimate	"In how many cases their final wealth will fall below the invested amount?" (Any numerical answer from 0 to 100 was allowed.)
Loss Probability - True Value	Number of cases out of 100, in which the final wealth will fall below the invested amount based on the participant's chosen allocation.

Variable	Description
Low Correlation	A Dummy equal to 1 for the round where participants face the low correlation condition..
Numeracy	Numeracy Score between 0 and 4: The number of correct answers to the traditional format version of the Berlin Numeracy Test from Cokely, Galesic, Schulz, and Ghazal (2012).
Numerical Experience	Dummy equal to 1 if a participant was randomly assigned to this treatment.
Numerical x High Corr.	Interaction term equal to 1 if a participant is in the experience numerical treatment and faces the high correlation condition.
Overall Dependence	"Asset 1 and 2 move ..." (Three radio buttons from "in opposite directions" to "together".)
Owns Equity	Dummy equal to 1 if a participant answers yes to the following question "Do you own stocks or an equity mutual fund?"
Second Decision	Dummy equal to 1 if a participant is in the second round of the experiment.
Self-Assessed Patience	"Are you generally more patient or impatient? Please select a category between 0 ("very impatient") and 10 ("very patient")." (11 radio buttons.)
Self-Assessed Stats Knowledge	"How would you describe your knowledge about statistics?" (Four radio buttons from "good" to "bad".)
Sd(Risk Aversion)	The self-assessed risk aversion, standardized to have zero mean and a standard-deviation of one.
$Share_2$	The share invested in asset 2 out of an endowment of €10,000.

Variable	Description
Trading Frequency	"How often do you trade stocks or equity funds?" (Six items: More than once a week. Every 1-4 weeks. Every 1-3 months. Every 4-12 months. Less than once a year. Never.)
Time	The total time spent with the information (pictures) about asset returns in seconds
Upside Dependence	"Given that asset 1's price increases, I expect asset 2 to..." (Three radio buttons from "decrease" to "increase".)
Wealth excl. RE	"Which of the following categories describes your financial wealth best (balances on all checking and savings and brokerage accounts, NO real estate)" (7 items: 0 to 1,000 Euros. 1,000 to 5,000 Euros. 5,000 to 20,000 Euros. 20,000 to 50,000 Euros. 50,000 to 100,000 Euros. >100,000 Euros. No entry.)
Willingness to take Risks (1-5)	Self-reported: "Please estimate your willingness to take financial risk." (Five radio buttons from "not willing to accept any risk" to "willing to accept substantial risk to potentially earn a greater return".)

Table B2: Experiment 1, 2, and 3: Asset Allocation and Risk Aversion

Sd(Risk Aversion) is self-assessed risk aversion, standardized to have zero mean and a standard-deviation of one. We run random effects regressions to take account of participant-specific effects. *t*-stats are reported in parentheses. 1/2/3 asterisks denote significance at the 10%/5%/1%-level.

	(1) $Share_2$ *Experiment 1*	(2) $Share_2$ *Experiment 2*	(3) $Share_2$ *Experiment 3*
Numerical x High Corr.	-0.0943^{***}	-0.0477^{**}	-0.0098
	(-2.56)	(-1.59)	(0.27)
Graphical x High Corr.	-0.1268^{***}	-0.1299^{***}	-0.0644^{*}
	(-3.41)	(-4.47)	(-1.73)
Numerical Experience	0.0554^{*}	0.0357^{*}	-0.0657
	(1.91)	(1.22)	(-2.24)
Graphical Experience	0.1192^{***}	0.0824^{***}	0.0016^{***}
	(4.06)	(2.92)	(0.05)
High Correlation	0.0206	-0.0188	-0.0162
	(0.80)	(-0.88)	(-0.64)
sd(Risk Aversion)	0.0057	0.0406^{***}	0.0296^{***}
	(0.61)	(4.06)	(3.12)
Constant	0.3101^{***}	0.2971^{***}	0.4501^{***}
	(15.17)	(14.41)	(22.22)
Random Effects	YES	YES	YES
No. obs.	572	892	606

Table B3: Experiment 1: Correlation Perception

The panels show the frequency of each answer-category for questions on beliefs about dependence. Boxes around numbers indicate correct answers. All answers are shown by Treatment and condition. Below Panels A1-2 and B1-2, you will find the mean category for each treatment and condition and differences between these means by treatment. *t*-stats are reported in parentheses. 1/2/3 asterisks denote significance at the 10%/5%/1%-level.

	Description		Numerical Experience		Graphical Experience	
	Low Corr	High Corr	Low Corr	High Corr	Low Corr	High Corr
Panel A1 (Upside Dependence): Given that asset 1's price increases, I expect asset 2 to...						
decrease 1	32	17	45	2	58	10
2	55	65	43	37	27	33
increase 3	11	16	8	57	7	49
mean	1.79	1.99	1.61	2.57	1.45	2.42
-low correlation	-	0.20**	-	0.96***	-	0.98***
		(2.35)		(11.25)		(10.06)
chi^2-test of differences						
-Diff in Corr in Description	-	-	-	0.75***	-	0.77***
-Diff in Corr in Numerical Experience	-	-	-	-	-	0.02
Panel A2 (Downside Dependence): Given that asset 1's price decreases, I expect asset 2 to...						
decrease 1	4	17	6	54	4	52
2	59	63	36	34	27	28
increase 3	35	18	54	8	61	12
mean	2.32	2.01	2.50	1.52	2.62	1.57
-low correlation	-	-0.31***	-	-0.98***	-	-1.05***
		(-3.73)		(-10.73)		(11.04)
chi^2-test of differences						
-Diff in Corr in Description	-	-	-	-0.67***	-	-0.75***
				(-5.77)		(−6.36)
-Diff in Corr in Numerical Experience	-	-	-	-	-	-0.08
						(-0.59)

	Description Low Corr	Description High Corr	Numerical Experience Low Corr	Numerical Experience High Corr	Graphical Experience Low Corr	Graphical Experience High Corr
Panel B1 (Frequency of Upside Co-Movement): Given that asset 1's price increases, I expect asset 2 to increase in ... out of 100 cases. (Any answer from 0 to 100 was allowed.)						
[0,20)	25	25	18	7	17	6
20	[6]	3	[8]	4	[13]	5
(20,40)	17	16	13	6	16	5
40	11	7	15	1	11	6
(40,60)	27	28	22	20	12	14
60	7	6	6	3	7	7
(60,80)	3	5	5	17	6	7
80	1	[2]	5	[12]	7	[15]
(80,100]	1	6	4	26	3	27
mean	34.33	38.27	40.65	63.07	39.22	62.89
- low correlation	-	3.94^{***}	-	22.43^{***}	-	23.67^{***}
		(3.29)		(3.54)		(3.58)
chi^2-test of differences						
-Diff in Corr in Description	-	-	-	18.48^{***}	-	19.73^{***}
-Diff in Corr in Numerical Experience	-	-	-	-	-	1.25
Panel B2 (Frequency of Downside Co-Movement): Given that asset 1's price decreases, I expect asset 2 to increase in ... out of 100 cases.						
[0,20)	21	34	3	29	3	33
20	4	[7]	6	[18]	1	[14]
(20,40)	15	13	11	13	10	8
40	10	6	6	5	8	4
(40,60)	26	27	21	15	11	11
60	9	4	13	3	12	7
(60,80)	8	4	16	1	22	3
80	[2]	1	[7]	4	[11]	3
(80,100]	3	2	13	8	14	6
mean	39.68	31.78	55.85	33.33	61.40	34.48
- low correlation	-	-7.91^{**}	-	-22.52^{***}	-	-26.92^{***}
		(−2.40)		(−6.39)		(−7.52)
chi^2-test of differences						
-Diff in Corr in Description	-	-	-	-14.61^{***}	-	-19.02^{***}
				(−3.30)		(−4.27)
-Diff in Corr in Numerical Experience	-	-	-	-	-	−4.40
						(−0.91)

Table B4: Experiment 2: Asset Allocation Regressions I

$Share_2$ is the investment in asset 2 (as a portfolio weight between 0 and 1). Asset 2 has a lower return and the same marginal distribution, compared to asset 1; it should thus only be interesting because of its diversification potential. Table B1 contains variable descriptions. In Specification (2), we exclude participants investing more than 50% in asset 2. In Specification (3), we look at participants' first decision only and thus is purely between-subjects. In Specification (4), we test for learning effects. We run random effects regressions (except for regression (3)) to take account of participant-specific effects. *t*-stats are reported in parentheses. 1/2/3 asterisks denote significance at the 10%/5%/1%-level.

	(1) $Share_2$ *All*	(2) $Share_2$ *$Share_2$ <=0.5*	(3) $Share_2$ *First Decision*	(4) $Share_2$ *All*
Numerical x High Corr.	-0.0477	-0.0592***	-0.0249	-0.0478
	(-1.59)	(-2.64)	(-0.41)	(-1.59)
Graphical x High Corr.	-0.1299***	-0.0885***	-0.1518**	-0.1300***
	(-4.47)	(-3.94)	(-2.56)	(-4.47)
Numerical Experience	0.0321	0.0493**	0.0059	0.0321
	(1.08)	(2.02)	(0.14)	(1.09)
Graphical Experience	0.0867***	0.0528**	0.0889**	0.0870***
	(3.03)	(2.18)	(2.15)	(3.04)
High Correlation	-0.0188	-0.0195	0.0014	0.0007
	(-0.88)	(-1.22)	(0.03)	(0.02)
Learning				-0.0390
				(-0.96)
Second Decision				0.0226
				(0.96)
Constant	0.2966***	0.2445***	0.2931***	0.2855***
	(14.20)	(14.08)	(9.65)	(11.94)
Random Effects	YES	YES	NO	YES
No. obs.	892	789	446	892

Table B5: Experiment 2: Asset Allocation Regressions II

The regressions for this table are analogous to Table B4. *Last Corr High* is a dummy equal to 1 if participants' last draw pictures a high correlation. *First Corr High* is a dummy equal to 1 if participants' last draw pictures a high correlation. *Last Return Asset 1* and *Last Return Asset 2* are the participant's last returns sampled for asset 1 and 2 respectively. *First Return Asset 1* and *First Return Asset 2* are the participant's first returns sampled for asset 1 and 2 respectively. In specifications (1) to (4), we analyze the effect of experienced return histories and thus only include participants with variation in observed returns, i.e., the description treatment is excluded. In specification (5), we only include participants with a low sampling error, namely participants who sampled a correlation between -0.55 and -0.65 in the low and between 0.55 and 0.65 in the high correlation condition. We run random effects regressions to take account of participant-specific effects. t-stats are reported in parentheses. 1/2/3 stars denote significance at the 10/5/1%-level.

	(1) $Share_2$ *All*	(2) $Share_2$ *Last Corr*	(3) $Share_2$ *First Corr*	(4) $Share_2$ *Last/First Ret*	(5) $Share_2$ *Real. Corr. +/- 5pp*
Last Corr High		-0.0168			
		(-0.75)			
First Corr High			0.0265		
			(1.18)		
Last Return Asset 1				-0.0608	
				(-0.89)	
Last Return Asset 2				0.0177	
				(0.26)	
First Return Asset 1				-0.0859	
				(-1.32)	
First Return Asset 2				-0.0961	
				(-1.44)	
Numerical x High Corr.					-0.0858*
					(1.88)
Graphical x High Corr.	-0.0821***	-0.0816***	-0.0830***	-0.0862***	-0.1825***
	(-2.74)	(-2.71)	(-2.77)	(-2.87)	(-3.71)
Numerical Experience					0.0694*
					(1.70)
Graphical Experience	0.0546*	0.0546*	0.0685*	0.0550*	0.1051***
	(1.93)	(1.93)	(1.94)	(1.90)	(2.60)
High Correlation	-0.0665***	-0.0567**	-0.0818***	-0.0602**	-0.0188
	(-3.03)	(-2.21)	(-3.21)	(-2.72)	(-0.99)
Constant	0.3287***	0.3322***	0.3227***	0.3370***	0.2966***
	(15.86)	(15.65)	(15.13)	(15.65)	(14.21)
Random Effects	YES	YES	YES	YES	YES
No. obs.	608	608	608	608	474

Table B6: Experiment 2: Correlation Perception

The panels show the frequency of each answer-category for questions on beliefs about dependence. Boxes around numbers indicate correct answers. All answers are shown by treatment and condition. Below Panels A1-2 and B1-2, you will find the mean category for each treatment and condition and differences between these means by treatment. *t*-stats are reported in parentheses. 1/2/3 asterisks denote significance at the 10%/5%/1%-level.

	Description		Numerical Experience		Graphical Experience	
	Low Corr	High Corr	Low Corr	High Corr	Low Corr	High Corr
Panel A1 (Upside Dependence): Given that asset 1's price increases, I expect asset 2 to...						
decrease 1	[72]	42	[77]	21	[92]	25
2	49	49	46	39	45	39
increase 3	21	[51]	18	[81]	26	[99]
mean	1.64	2.06	1.58	2.43	1.60	2.45
-low correlation	-	0.42^{***}	-	0.85^{***}	-	0.86^{***}
		(4.63)		(9.79)		(10.35)
chi^2-test of differences						
-Diff in Corr in Description	-	-	-	0.43^{***}	-	0.44^{***}
				(3.69)		(3.79)
-Diff in Corr in Numerical Experience	-	-	-	-	-	0.01
						(0.12)
Panel A2 (Downside Dependence): Given that asset 1's price decreases, I expect asset 2 to...						
decrease 1	19	[36]	9	[76]	20	[95]
2	47	54	43	35	41	40
increase 3	[76]	52	[89]	30	[102]	28
mean	2.40	2.11	2.56	1.67	2.50	1.59
-low correlation	-	-0.29^{***}	-	-0.89^{***}	-	-0.91^{***}
		(-3.25)		(-10.48)		(-11.19)
chi^2-test of differences						
-Diff in Corr in Description	-	-	-	-0.60^{***}	-	-0.62^{***}
				(-5.45)		(-5.75)
-Diff in Corr in Numerical Experience	-	-	-	-	-	-0.02
						(-0.18)

	Description		Numerical Experience		Graphical Experience	
	Low Corr	High Corr	Low Corr	High Corr	Low Corr	High Corr
Panel B1 (Frequency of Upside Co-Movement): Given that asset 1's price increases, I expect asset 2 to increase in ... out of 100 cases. (Any answer from 0 to 100 was allowed.)						
[0,20)	36	32	35	20	38	28
20	13	10	15	7	16	6
(20,40)	24	23	19	9	32	9
40	7	14	12	6	16	6
(40,60)	43	39	34	29	29	28
60	4	7	11	5	9	7
(60,80)	10	5	5	13	12	17
80	1	7	6	14	7	28
(80,100]	2	10	6	33	4	34
mean	33.56	41.91	38.12	53.79	36.45	56.46
- low correlation	-	7.35^{***}	-	15.67^{***}	-	20.01^{***}
		(2.64)		(4.87)		(6.83)
chi^2-test of differences						
-Diff in Corr in Description	-	-	-	8.32^{**}	-	12.66^{***}
				(2.27)		(3.37)
-Diff in Corr in Numerical Experience	-	-	-	-	-	4.34
						(1.03)
Panel B2 (Frequency of Downside Co-Movement): Given that asset 1's price decreases, I expect asset 2 to increase in ... out of 100 cases.						
[0,20)	26	50	19	61	17	73
20	6	8	8	12	4	24
(20,40)	25	19	14	22	25	14
40	11	4	13	1	17	4
(40,60)	42	34	28	22	33	23
60	7	10	13	3	15	4
(60,80)	11	7	17	7	24	8
80	9	8	14	3	14	7
(80,100]	5	2	15	10	14	6
mean	42.27	34.41	50.30	31.67	50.39	29.22
- low correlation	-	-7.86^{***}	-	-18.63^{***}	-	-21.17^{***}
		(−2.73)		(−6.03)		(−7.74)
chi^2-test of differences						
-Diff in Corr in Description	-	-	-	-10.77^{***}	-	-13.31^{***}
				(−2.94)		(−3.95)
-Diff in Corr in Numerical Experience	-	-	-	-	-	−2.54

Table B7: Experiment 3: Asset Allocation Regressions I

Share$_2$ is the investment in asset 2 (as a portfolio weight between 0 and 1). Asset 2 has a lower return and the same marginal distribution, compared to asset 1; it should thus only be interesting because of its diversification potential. Table B1 contains variable descriptions. In Specification (2), we exclude participants investing more than 50% in asset 2. In Specification (3), we look at participants' first decision only and thus is purely between-subjects. In Specification (4), we test for learning effects. We run random effects regressions (except for regression (3)) to take account of participant-specific effects. *t*-stats are reported in parentheses. 1/2/3 asterisks denote significance at the 10%/5%/1%-level.

	(1) Share$_2$ *All*	(2) Share$_2$ *Share$_2$ <=0.5*	(3) Share$_2$ *First Decision*	(4) Share$_2$ *All*
Numerical x High Corr.	0.0098	0.0238	0.0400	0.0082
	(0.27)	(0.81)	(0.69)	(0.23)
Graphical x High Corr.	-0.0644*	-0.0064	-0.0205	-0.0670*
	(-1.73)	(-0.22)	(-0.35)	(-1.82)
Numerical Experience	-0.0641**	-0.0305	-0.1135***	-0.0635**
	(-2.17)	(-1.23)	(-2.86)	(-2.15)
Graphical Experience	0.0045	0.0128	-0.0541	0.0056
	(0.15)	(0.50)	(-1.33)	(0.19)
High Correlation	-0.0162	-0.0308	-0.0303	-0.0064
	(-0.64)	(-1.47)	(-0.76)	(-0.20)
Learning				-0.0143
				(-0.37)
Second Decision				-0.0293
				(-1.20)
Constant	0.4486***	0.3432***	0.4964***	0.4622***
	(22.07)	(19.82)	(18.35)	(19.89)
Random Effects	YES	YES	NO	YES
No. obs.	606	456	303	606

Table B8: Experiment 3: Asset Allocation Regressions II

Regressions in this table are analogous to Table B7. *Last Corr High* is a dummy equal to 1 if participants' last draw pictures a high correlation. *First Corr High* is a dummy equal to 1 if participants' last draw pictures a high correlation. *Last Return Asset 1* and *Last Return Asset 2* are the participants last returns sampled for asset 1 and 2 respectively. *First Return Asset 1* and *First Return Asset 2* are the participants first returns sampled for asset 1 and 2 respectively. In Specifications (1) to (4), we analyze the effect of experienced return histories and thus only include participants with variation in observed returns, i.e. the description treatment is excluded. In Specification (5), we only include participants with a low sampling error, namely participants who sampled a correlation between -0.55 and -0.65 in the low and between 0.55 and 0.65 in the high correlation condition. We run random effects regressions to take account of subject-specific effects. t-stats are reported in parentheses. 1/2/3 asterisks denote significance at the 10%/5%/1%-level.

	(1) $Share_2$ *All*	(2) $Share_2$ *Last Corr*	(3) $Share_2$ *First Corr*	(4) $Share_2$ *Last/First Ret*	(5) $Share_2$ *Real. Corr. +/- 5pp*
Last Corr High		-0.0158			
		(-0.73)			
First Corr High			-0.0201		
			(-0.94)		
Last Return Asset 1				-0.0583	
				(-0.76)	
Last Return Asset 2				-0.0363	
				(-0.48)	
First Return Asset 1				-0.1143*	
				(-1.68)	
First Return Asset 2				-0.0026	
				(-0.04)	
Numerical x High Corr.					0.0069
					(0.17)
Graphical x High Corr.	-0.0742**	-0.0744**	-0.0733**	-0.0747**	-0.0531
	(-2.17)	(-2.18)	(-2.15)	(-2.17)	(-1.29)
Numerical Experience					-0.0729**
					(-2.35)
Graphical Experience	0.0686**	0.0696**	0.0685**	0.0668**	0.0010
	(2.35)	(2.38)	(2.34)	(2.26)	(0.03)
High Correlation	-0.0064	-0.0007	0.0013	-0.0043	-0.0162
	(-0.27)	(-0.03)	(0.05)	(-0.18)	(-0.62)
Constant	0.3845***	0.3904***	0.3910***	0.3955***	0.4486***
	(18.84)	(17.78)	(18.14)	(18.14)	(22.12)
Random Effects	YES	YES	YES	YES	YES
No. obs.	386	386	386	384	542

Table B9: Experiment 3: Attention Paid to Presentation Formats

Panel A shows the average total time spent with the information about asset returns by treatment. This information is shown by condition as well as decision round. Panel B shows the allocation to the diversification asset 2 for participants who spent above (below) median time to view the information about the asset returns. Median splits were conducted for each treatment×condition separately. 1/2/3 asterisks denote significance at the 10%/5%/1%-level.

Panel A: Time in Seconds by Presentation Format

Time by Condition	Low Correlation	High Correlation	Difference	t-stat
Description	93.52	86.74	-6.78	-0.60
Numerical Experience	113.14	122.00	8.86	0.94
Graphical Experience	104.12	107.07	2.96	0.50

Time by Decision Round	Round 1	Round 2	Difference	t-stat
Description	112.50	67.76	-44.74***	-4.27
Numerical Experience	120.51	114.62	-5.89	-0.62
Graphical Experience	116.15	95.04	-21.11***	-3.81

Panel B: Attention Paid and Asset Allocation

	Low Correlation	High Correlation	Difference	t-stat
Total Time < Median				
Description	44.22%	46.63%	2.41%	0.54
Numerical Experience	36.03%	35.44%	-0.59%	-0.13
Graphical Experience	44.90%	36.95%	-7.95%*	-1.89
Total Time > Median				
Description	45.51%	39.85%	-5.65%	-1.31
Numerical Experience	40.93%	40.23%	-0.70%	0.17
Graphical Experience	45.72%	37.55%	-8.17%**	-2.13

Table B10: Experiment 3: Correlation Perception

The panels show the frequency of each answer-category for questions on beliefs about dependence. Boxes around numbers indicate correct answers. All answers are shown by treatment and condition. Below Panels A1-2 and B1-2, you will find the mean category for each treatment and condition and differences between these means by treatment. *t*-stats are reported in parentheses. 1/2/3 asterisks denote significance at the 10%/5%/1%-level.

	Description		Numerical Experience		Graphical Experience	
	Low Corr	High Corr	Low Corr	High Corr	Low Corr	High Corr
Panel A1 (Upside Dependence): Given that asset 1's price increases, I expect asset 2 to...						
decrease 1	[66]	23	[64]	16	[59]	18
2	20	18	9	12	7	14
increase 3	15	[60]	8	[52]	12	[47]
don't know	9	9	18	19	16	15
mean	1.50	2.37	1.31	2.45	1.40	2.37
-low correlation	-	0.87^{***}	-	1.14^{***}	-	0.97^{***}
		(7.84)		(9.90)		(7.68)
chi^2-test of differences						
-Diff in Corr in Description	-	-	-	0.27	-	0.10
-Diff in Corr in Numerical Experience	-	-	-	-	-	-0.17
Panel A2 (Downside Dependence): Given that asset 1's price decreases, I expect asset 2 to...						
decrease 1	11	[54]	10	[37]	6	[50]
2	14	17	10	11	8	10
increase 3	[75]	29	[65]	39	[67]	20
don't know	10	10	14	12	18	19
mean	2.64	1.75	2.65	2.02	2.75	1.62
-low correlation	-	-0.89^{***}	-	-0.62^{***}	-	-1.13^{***}
		(-8.02)		(-4.97)		(-9.74)
chi^2-test of differences						
-Diff in Corr in Description	-	-	-	0.28	-	-0.22
				(1.61)		(-1.28)
-Diff in Corr in Numerical Experience	-	-	-	-	-	-0.50^{***}
						(-2.75)

	Description Low Corr	Description High Corr	Numerical Experience Low Corr	Numerical Experience High Corr	Graphical Experience Low Corr	Graphical Experience High Corr
Panel B1 (Frequency of Upside Co-Movement): Given that asset 1's price increases, I expect asset 2 to increase in ... out of 100 cases. (Any answer from 0 to 100 was allowed.)						
[0,20)	67	39	19	10	11	9
20	7	7	10	3	19	4
(20,40)	10	8	23	11	18	9
40	2	7	4	6	11	6
(40,60)	11	16	21	23	15	14
60	4	3	6	8	8	14
(60,80)	3	9	9	19	5	16
80	2	6	5	4	4	11
(80,100]	4	15	2	15	3	11
mean	22.95	40.27	38.84	53.73	38.83	54.73
- low correlation	-	17.33^{***}	-	14.89^{***}	-	15.90^{***}
		(5.10)		(4.25)		(4.99)
chi^2-test of differences						
-Diff in Corr in Description	-	-	-	-2.44	-	-1.42
-Diff in Corr in Numerical Experience	-	-	-	-	-	1.02
Panel B2 (Frequency of Downside Co-Movement): Given that asset 1's price decreases, I expect asset 2 to increase in ... out of 100 cases.						
[0,20)	50	60	42	49	2	25
20	5	10	6	9	1	11
(20,40)	10	11	6	5	10	19
40	6	4	4	2	12	8
(40,60)	10	10	13	9	16	18
60	5	4	2	2	10	6
(60,80)	11	6	2	7	30	7
80	3	1	5	7	13	3
(80,100]	10	4	19	9	5	2
mean	34.94	24.57	39.14	32.49	58.41	35.77
- low correlation	-	-10.36^{***}	-	-6.65	-	-22.65^{***}
		(-2.81)		(-1.41)		(-7.58)
chi^2-test of differences						
-Diff in Corr in Description	-	-	-	3.72	-	-12.28^{***}
				(0.73)		(-2.92)
-Diff in Corr in Numerical Experience	-	-	-	-	-	-16.00^{***}
						(-3.14)

Table B11: Experiment 3 with Graphical Description: Summary Stats

This table reports summary statistics (means and standard deviations) for participants in Experiment 3 by treatment. In addition to the description treatment and the two sampling treatments, a graphical description treatment is included. Numbers in parentheses indicate the range of possible values. *Financial literacy* is measured as the number of correctly answered questions in the test proposed by Fernandes, Lynch, and Netemeyer (2014). *Numeracy* is measured as the number of correctly answered questions in the test proposed by Cokely, Galesic, Schulz, and Ghazal (2012). Table B1 contains variable descriptions.

	Des. N=110		Des. Graph N=104		Exp. Num. N=96		Exp. Graph. N=92	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Age	22.61	4.57	23.22	6.49	21.54	2.85	22.61	4.57
Fraction Male	0.46	0.50	0.51	0.50	0.57	0.50	0.46	0.50
Owns Equity	0.20	0.40	0.24	0.43	0.33	0.47	0.20	0.40
Interested in Financial Markets	0.62	0.49	0.65	0.48	0.64	0.48	0.62	0.49
Willingness to Take Risks (1-5)	2.82	1.04	2.93	1.15	2.87	1.12	2.82	1.04
Has Taken Statistics Course	0.63	0.49	0.63	0.49	0.58	0.50	0.63	0.49
Self-Assessed Stats Knowledge (1-4)	2.62	0.89	2.51	0.93	2.44	1.11	2.62	0.89
Financial Literacy (0-12)	6.74	2.57	7.13	2.26	7.15	2.25	6.74	2.57
Numeracy (0-4)	1.06	1.28	1.07	1.25	1.27	1.33	1.06	1.28

Table B12: Experiment 3 with Graphical Description: Allocation

Panel A shows the average allocation into the diversification asset 2 in % by condition and treatment. Panel B shows the difference in differences between conditions by treatments.

Panel A: Descriptive Statistics on Allocation

	Low Correlation	High Correlation	Difference	*t*-stat	Average
Description	44.86%	43.24%	-1.62%	-0.52	44.05%
Description Graphical	50.39%	57.76%	7.38%**	2.32	54.07%
Numerical Experience	38.45%	37.80%	-0.64%	-0.21	38.13%
Graphical Experience	45.05%	36.90%	-8.15%***	-2.88	40.97%

Panel B: Differences between Treatments

	Diff in Diff	*t*-stat	Diff in Average	*t*-stat
Description Graphical - Description	7.90%**	2.15	10.02%***	4.48
Numerical Experience - Description	0.98%	0.26	-5.92%***	-2.73
Numerical Experience - Description Graphical	-8.02%**	-2.12	15.94%***	7.25
Graphical Experience - Description	-6.52%*	-1.66	-3.08%	-1.44
Graphical Experience - Descripton Graphical	-15.53%***	-3.97	-13.10%***	-6.04
Graphical Experience - Numerical Experience	-7.51%**	-2.19	2.84%	1.37

Table B13: Summary Statistics: Additional Variables

This table reports additional summary statistics (means) for variables, which were assessed, but not discussed in the paper for Experiments 1 (Panel A), 2 (Panel B), and 3 (Panel C) by treatment and condition. The exact wording of the questions can be found in Appendix D.
"Related to Div. or Vola" is a variable indicating how many answers to the question "Please describe briefly why you chose this allocation" in Experiment 2 referred to diversification or portfolio volatility. Numbers in parentheses indicate the range of possible values.

Panel A: Summary Statistics for Additional Variables Experiment 1

	Description		Exp. Numerical		Exp. Graphical	
	Low	High	Low	High	Low	High
Est. p of a large loss (percent)	14.44	14.93	14.28	9.67	13.82	14.15
True p of a large loss (percent)	1.45	4.17	1.44	3.99	1.14	4.02
Est. p of a large gain (percent)	20.64	21.52	20.96	25.25	19.27	24.66
True p of a large gain (percent)	2.27	4.33	2.03	4.53	1.85	4.29
Exp. portfolio value (Euros)	10,874	10,976	11,057	12,160	11,419	12,455
Est. portfolio risk (1-7)	4.26	4.34	4.57	4.36	4.23	4.17
Feeling informed (1-7)	3.11	3.18	2.85	2.94	3.24	3.18
Confidence	4.06	4.15	3.88	4.30	4.41	4.34

Panel B: Summary Statistics for Additional Variables Experiment 2

	Description		Exp. Numerical		Exp. Graphical	
	Low	High	Low	High	Low	High
Est. p of a large loss <-20% (percent)	8.93	8.17	8.99	7.90	8.29	8.72
True p of a large loss <-20% (percent)	2.35	4.36	1.96	4.35	1.93	4.38
Est. p of a large gain >20%(percent)	13.01	16.24	14.40	16.50	14.86	17.12
True p of a large gain >20%(percent)	2.83	4.50	2.50	4.57	2.42	4.57
Exp. portfolio value (Euros)	10,773	12,140	10,036	11,021	9,813	11,853
Est. portfolio risk (1-7)	4.50	4.47	4.50	4.60	4.25	4.42
Confidence	5.08	4.93	4.95	5.01	5.04	5.17
Related to Div. or Vola (percent)	30.69	31.46	36.08	29.21	34.57	41.56
Gut feeling (1-7)	3.49	3.70	4.17	3.96	3.85	3.74
1 = asset 1 riskier, 3 = asset 2 riskier	2.11	2.14	2.18	2.09	1.98	2.24
Asset 2 diversifies losses (1-7)	3.28	3.24	3.72	3.22	3.64	3.10
Asset 2 enhances gains (1-7)	2.60	2.63	2.67	2.64	2.82	2.49
Risk-return tradeoff feels right (1-7)	5.13	5.47	5.33	5.52	5.65	5.31

Panel C: Summary Statistics for Additional Variables Experiment 3						
	Description		Exp. Numerical		Exp. Graphical	
	Low	High	Low	High	Low	High
Est. p of a large loss (percent)	11.12	11.20	17.60	15.62	16.03	15.07
True p of a large loss (percent)	0.53	2.00	0.35	2.02	0.20	1.83
Est. p of a large gain (percent)	19.55	16.66	29.84	28.58	25.15	26.39
True p of a large gain (percent)	3.18	9.23	2.90	10.19	2.01	9.95
Exp. portfolio value (Euros)	11,666	11,114	10,415	10,696	12,029	23,732
Est. portfolio risk (1-7)	4.05	4.10	4.49	4.32	4.40	4.67
Feeling informed (1-7)	3.34	3.40	2.95	3.03	2.67	2.81
Confidence	4.13	4.22	4.13	4.29	3.72	3.87

C Discussion of Additional Presentation Format: Graphical Description

In this section, we report results of Experiment 3 including the graphical description treatment we explored. In this graphical descriptive way to communicate the riskiness of the two assets, participants face a three-dimensional bar chart, where the length of the bars illustrates the frequency of occurrence of the joint return ranges (see figure A2). We include reading examples in order to ease understanding.

Summary statistics for Experiment 3 including the graphical description treatment are reported in Table B11. They indicate that the randomization worked: Participants in the graphical description treatment are not significantly different from participants in the other treatments. The allocation decision in Experiment 3, including the graphical description treatment, is reported in Table B12. With regard to the three-dimensional graphical description treatment, we find that participants diversify 7.38 percentage points more, when correlation increases (i.e., they make a worse investment decision compared to correlation neglect in the numerical description treatment). One reason might be that three-dimensional graphs are a presentation format, that participants are unfamiliar with. Thus they might have trouble correctly understanding the benefits of diversification based on this presentation format. We take the fact, that a relatively large fraction (23%) of participants allocated their endowment equally across the two assets as evidence in support of this explanation. However, when we analyze participants' beliefs about dependence, we find that beliefs react consistently (i.e., participants belief dependence is higher when correlation increases). A simple misunderstanding of the direction of the axes in the graph, for example, cannot be the explanation for the failure of our graphical description treatment to alleviate correlation neglect. This result is in line with Kallir and Sonsino (2009) and our other results, where we often find that participants' correct beliefs about dependence are not sufficient to alleviate correlation neglect, e.g., across the different treatments in Experiment 3. Successful treatments, in particular graphical experience sampling, do not just lead to a good understanding of correlation. They seem to also help participants better understand the benefits of diversification, so that correlation neglect is alleviated.

D Instructions and Questions

D.1 Experiments 1 and 3

All instructions and questions, translated from German into English. Instructions were the same for Experiment 1 and 3 if not explicitly stated otherwise

Introduction:

Screen 1 (Welcome Screen):

Dear participant,

Thanks for participating in this experiment. The aim of this Experiment is to better understand the investment choices of retail investors. You will be asked to make two investment decisions and answer a few additional questions.

For your participation in this experiment, you will receive a performance-based compensation, which depends on your investment decision. After the experiment, we will randomly select whether you will receive the compensation based on your first or second investment decision. You will receive your compensation after completing the experiment.

The experiment will take (including time for reading of instructions, the survey, and the payout of your compensation) around 60 minutes. We politely ask you to not communicate with other participants during the experiment. As soon as you leave this screen, Section 1 of the experiment begins.

If you have any questions, please raise your hand.

Screen 2 (Instructions):

On the following screens, you will be informed about the returns of two assets. Based on this information, you can get an idea of the possible joint returns of the two assets. Subsequently, you are asked to split your fictive wealth of €10,000 between the two assets. You can invest your entire wealth into one of the two assets or split it up between the two assets as desired. The average return per year of assets 1 and 2 is known:

Average return asset 1: 5% per year
Average return asset 2: 4% per year

You will receive a compensation that is based on your investment decision. We calculate this compensation based on a simulation of a one-year asset return for each of the two assets, according to the following formula:

```
[Investment_Asset1*(1*Return_Asset1)+Investment_Asset2*(1*Return_Asset2)]/1,000
```

As soon as you click "Continue", the experiment will begin.

Treatment$_\mathrm{i}$ (conditional on presentation format):

Screen 3 (Introduction to Round i):

Round i of the experiment starts now.

[Experience Treatments] After this screen, you will see 60 possible joint return realizations of the two assets, which are randomly drawn from their distribution. You will have sufficient time to view the 60 return pairs. If you do not continue, you will automatically enter the next section of the experiment after 10 minutes.

[Description Treatment] After this screen, you will see the possible joint returns of the two assets in a table. The probability for joint returns is included in the table. You will have sufficient time to view the table. If you do not continue, you will automatically enter the next section of the experiment after 10 minutes.

[Graphical Description Treatment (Experiment 3 only)] After this screen, you will see the possible joint returns of the two assets in a graph. The probability for joint returns is also presented in the graph. You will have sufficient time to view the graph. If you do not continue, you will automatically enter the next section of the experiment after 10 minutes.

Subsequently, you are asked to split your fictive wealth of €10,000 between the two assets. Your compensation at the end of the experiment depends on this investment decision and newly simulated returns of both assets.

Screens 4-13 (Presentation of Return Distribution):

[Participants view the information on joint returns of the two assets in the respective presentation format they are randomly allocated to. Up to a maximum viewing time of 10 minutes, participants determine themselves how long to view each return pair (experience sampling treatments) or the frequency table of return pairs (description treatment) and click "Continue" to continue. They cannot go back to previous screens after clicking "Continue".]

Investment Decision:

Screen 14:

You have €10,000 at your disposal. Your task is to split this wealth between the two assets. How much do you want to invest in asset 1, how much in asset 2? (Note: The two investments have to add up to €10,000.)

Investment in asset 1 (in €):
Investment in asset 2 (in €):

Elicitation of Beliefs:

Screen 15 (Dependence):

- 'Assets 1 and 2 move ...' (Five radio buttons from 'in opposite directions' to 'together'., additional option to select 'I don't know in Experiment 3' only)
- 'Given that asset 1's price decreases, I expect asset 2 to...' (Three radio buttons from 'decrease' to 'increase'. Additional option to select 'I don't know in Experiment 3' only)
- 'Given that asset 1's price increases, I expect asset 2 to...' (Three radio buttons from 'decrease' to 'increase'. Additional option to select 'I don't know in Experiment 3' only)
- 'Given that asset 1's price decreases, I expect asset 2's price to increase in ... out of 100 cases.' (Any numerical answer from 0 to 100 was allowed.)
- 'Given that asset 1's price increases, I expect asset 2's price to increase in ... out of 100 cases.' (Any numerical answer from 0 to 100 was allowed.)

Screen 16 (Portfolio Characteristics):

- 'Given your investment decision, what do you expect your portfolio value to be in one year?' (Any numerical answer ≥ 0 was allowed.)
- 'In how many out of 100 cases do you expect to lose money (a final portfolio value of less than €10,000 in one year)?' (Any numerical answer between 0 and 100 was allowed.)
- 'In how many out of 100 cases do you expect your final portfolio value to be more than €12,000 in one year?' (Any numerical answer between 0 and 100 was allowed.)
- 'In how many out of 100 cases do you expect your final portfolio value to be less than €8,000 in one year?' (Any numerical answer between 0 and 100 was allowed.)
- 'How risky do you perceive your portfolio to be?' (Seven radio buttons from 'risk-free' to 'very risky'.)
- 'How confident are you about your investment decision?' (Seven radio buttons from 'not confident at all' to 'very confident'.)
- 'How informed do you feel when making this investment decision?' (Seven radio buttons from 'not at all informed' to 'completely informed'.)

Survey:

Screen 17 (Basic Characteristics):

- Self-reported: 'Please estimate your willingness to take financial risk.' (Five radio buttons from 'not willing to accept any risk' to 'willing to accept substantial risk to potentially earn a greater return'.)
- 'Do you own stocks or an equity mutual fund?' (Answer: 'yes' or 'no'.)
- 'Are you generally interested in stock or financial markets?' (Answer: 'yes' or 'no'.)
- 'Have you attended a university statistics course?' (Answer: 'yes' or 'no'.)
- 'How would you describe your knowledge about statistics?' (Four radio buttons from 'good' to 'bad'.)
- 'Have you attended a university finance course?' (Answer: 'yes' or 'no'.)
- 'How would you describe your knowledge about investments?' (Four radio buttons from 'good' to 'bad'.)

- 'What's your age?' (Answer: Any numerical answer between 16 and 80 was allowed.)
- 'Are you male or female?' (Answer: 'male' or 'female'.)

Screen 18 (Financial Literacy I):

- 'You can select either one of two stock portfolios A and B. Portfolio A is worth €10,000 and fully invested in a randomly selected firm out of the 30 firms in the German stock index DAX. Portfolio B is worth €10,000 and equally divides the investment across the 30 firms in the German stock index DAX.'
  - 'For which portfolio do you expect a higher return?' (Answer: A, B, or same return. Question included in Experiment 3 only)
  - 'For which portfolio do you expect a higher risk?' (Answer: A, B, or same risk. Question included in Experiment 3 only)

- Imagine that the interest rate on your savings account was 1% per year and inflation was 2% per year. After 1 year, would you be able to buy:
  - More than today with the money in this account
  - Exactly the same as today with the money in this account
  - *Less than today with the money in this account*
  - Don't know
  - Refuse to answer

  (Item (1) from Fernandes, Lynch, and Netemeyer (2014).)

- Do you think that the following statement is true or false? 'Bonds are normally riskier than stocks.'
  - True
  - *False*
  - Don't know
  - Refuse to answer

  (Item (2) from Fernandes, Lynch, and Netemeyer (2014).)

- Considering a long time period (for example, 10 or 20 years), which asset described below normally gives the highest return?
  - Savings accounts
  - *Stocks*
  - Bonds
  - Don't know
  - Refuse to answer

  (Item (3) from Fernandes, Lynch, and Netemeyer (2014).)

- Normally, which asset described below displays the highest fluctuations over time?
  - Savings accounts
  - *Stocks*
  - Bonds
  - Don't know
  - Refuse to answer

  (Item (4) from Fernandes, Lynch, and Netemeyer (2014).)

Screen 19 (Financial Literacy II):

- When an investor spreads his money among different assets, does the risk of losing a lot of money:
  - Increase
  - *Decrease*
  - Stay the same
  - Don't know
  - Refuse to answer

  (Item (5) from Fernandes, Lynch, and Netemeyer (2014).)

- Do you think that the following statement is true or false? 'If you were to invest €10,000 in a stock mutual fund, it would be possible to have less than €10,000 when you withdraw your money.'
  - *True*
  - False
  - Don't know
  - Refuse to answer

  (Item (6) from Fernandes, Lynch, and Netemeyer (2014).)

- Do you think that the following statement is true or false? 'A stock mutual fund combines the money of many investors to buy a variety of stocks.'
  - *True*
  - False
  - Don't know
  - Refuse to answer

  (Item (7) from Fernandes, Lynch, and Netemeyer (2014).)

- Do you think that the following statement is true or false? 'A 15-year mortgage typically requires higher monthly payments than a 30-year mortgage, but the total interest paid over the life of the loan will be less.'
  - *True*
  - False
  - Don't know
  - Refuse to answer

  (Item (9) from Fernandes, Lynch, and Netemeyer (2014).)

Screen 20 (Financial Literacy III):

- Suppose you have 100 € in a savings account and the interest rate is 20% per year and you never withdraw money or interest payments. After 5 years, how much would you have in this account in total?
  - *More than 200 €*
  - Exactly 200 €
  - Less than 200 €
  - Don't know
  - Refuse to answer

  (Item (10) from Fernandes, Lynch, and Netemeyer (2014).)

- Which of the following statements is correct?
  - Once one invests in a mutual fund, one cannot withdraw the money in the first year
  - *Mutual funds can invest in several assets, for example in both stocks and bonds*
  - Mutual funds pay a guaranteed rate of return, which depends on their past performance
  - None of the above
  - Don't know
  - Refuse to answer

  (Item (11) from Fernandes, Lynch, and Netemeyer (2014).)

- Which of the following statements is correct? If somebody buys a bond of firm B:
  - He owns a part of firm B
  - *He has lent money to firm B*
  - He is liable for firm B's debts
  - None of the above
  - Don't know
  - Refuse to answer

  (Item (12) from Fernandes, Lynch, and Netemeyer (2014).)

- Suppose you owe €3,000 on your credit card. You pay €30 each month. At an annual percentage rate of 12% (or 1% per month), how many years would it take to eliminate your credit card debt if you made no additional new charges?
  - Less than 5 years
  - Between 5 and 10 years
  - Between 10 and 15 years
  - *Never*
  - Don't know
  - Refuse to answer

  (Item (13) from Fernandes, Lynch, and Netemeyer (2014).)

Note: This test is an adapted version of the financial literacy test in Fernandes, Lynch, and Netemeyer (2014). Item (8) from the original test was left out since the experiments were conducted in Germany (it is a question related to 401(k) plans and therefore specific to the U.S. setting).

Screen 21 (Numeracy):

- 'Out of 1,000 people in a small town 500 are members of a choir. Out of these 500 members in a choir, 100 are men. Out of the 500 inhabitants that are not in a choir, 300 are men. What is the probability that a randomly drawn man is a member of the choir? Please indicate the probability in percent. This means that you should not use any commas or dots.' (Numerical answer between 0 and 100. Correct answer: 25)
- 'Imagine we are throwing a five-sided die 50 times. On average, out of these 50 throws, how many times would this five-sided die show an odd number (1, 3 or 5)?' (Numerical answer between 0 and 50. Correct answer: 30)
- 'Imagine we are throwing a loaded die (6 sides). The probability that the die shows a 6 is twice as high as the probability of each of the other numbers. On average, out of these 70 throws how many times would the die show the number 6?' (Numerical answer between 0 and 70. Correct answer: 20)
- 'In a forest, 20% of the mushrooms are red, 50% brown, and 30% white. A red mushroom is poisonous with a probability of 20%. A mushroom that is not red is poisonous with a probability of 5%. What is the probability that a poisonous mushroom in the forest is red?' (Numerical answer between 0 and 100. Correct answer: 50)

Note: This test is the traditional format version of the Berlin Numeracy Test from Cokely, Galesic, Schulz, and Ghazal (2012).

D.2 Experiment 2

All instructions and questions, translated from German into English.

Introduction:

Screen 1 (Welcome Screen):

Welcome!

Thanks for participating in this experiment. The aim of this experiment is to better understand investment choices of retail investors. You will be asked to make two investment decisions and answer a few additional questions.

For your participation in this experiment, you will receive a of up to 13.50 Euros, which depends on your investment decision. After the experiment, we will randomly select whether you will receive a voucher of 5 Euros or the a compensation based on your investment decision. In case of a decision based compensation, it will be randomly selected whether it is based on your first or second investment decision. You will receive your compensation after completing the experiment.

Screen 2 (Personal Information):

- 'Are you generally interested in financial markets?' (Answer: 'yes' or 'no'.)
- 'Do you own stocks or an equity mutual fund?' (Answer: 'yes' or 'no'.)

- 'How often do you trade stocks or equity funds?'
  - More than once a week
  - Every 1-4 weeks
  - Every 1-3 months
  - Every 4-12 months
  - Less than once a year
  - Never
- 'Are you male or female?' (Answer: 'male' or 'female'.)
- 'What's your age?' (Answer: Any numerical answer between 16 and 80 was allowed.)
- 'Are you generally more patient or impatient? Please select a category between 0 ('very impatient') and 10 ('very patient')(11 radio buttons.)
- 'Which of the following categories describes you financial wealth best (balances on all checking and savings and brokerage accounts, NO real estate)
  - 0 to 1,000 Euros
  - 1,000 to 5,000 Euros
  - 5,000 to 20,000 Euros
  - 20,000 to 50,000 Euros
  - 50,000 to 100,000 Euros
  - $> 100,000$ Euros
  - No entry

Investment Decision:

Screen 3 (Investment Decision):

On the following screens, you will be informed about the returns of two assets. Based on this information, you can get an idea of the possible joint returns of the two assets. Subsequently, you are asked to split your fictive wealth of €10,000 between the two assets. You can invest your entire wealth into one of the two assets or split it up between the two assets as desired. The average return per year of assets 1 and 2 is known:

Average return asset 1: 5% per year
Average return asset 2: 4% per year

Screen 4 (Lottery):

Every 10th participant has the possibility to receive a performance based compensation. The amount will be determined with the help of a simulation. The expected value will be higher than 10.40 Euros and is based on your investment decision. The exact amount will be disclosed to you at the end of the experiment. All other participants will receive a fix amount of 5 Euros. Compensations will be paid via Amazon gift cards. In case you would like to receive such a gift card, you need to provide us with your email address at the end of this experiment. Detailed description of the performance based compensation: The potential compensation is calculated based on a simulation of a one-year asset return for each of the two assets, according to the following formula:

```
[Investment_Asset1*(1*Return_Asset1)+Investment_Asset2*(1*Return_Asset2)]/1,000
```

Example: Imagine, you have invested half of your endowment in asset 1 and half of it in asset 2. The simulation results in an annual return of +20% for asset 1 and -10% for asset 2. Your ficticious wealth will then be €5,000 * (1+20%) + €5,000 * (1-10%) = €5,000 * 1.20 + €5,000 * 0.90 = €10,500. Your potential performance based compensation will then amount to €10,500 / 1,000 = €10.50.

Overall, the experiment will take 20 minutes including the time for reading the instructions and answering the survey.

Screen 5 (Investment Decision 1 out of 2):

Round 1 of the experiment starts now.

[Experience Sampling Treatments] After this screen, you will see 60 possible joint return realizations of the two assets, which are randomly drawn from their distribution. For observing, you will have as much time as you want to. On the next page, you should view a graph depicting the joint returns of asset 1 and 2 in a simulation 1 (out of 60). In case you don't see a graph, please copy the link in your browser and try an alternative browser (e.g., Mozilla Firefox, Google Chrome or Safari) in order to participate in the experiment.

[Description Treatment] After this screen, you will see the possible joint returns of the two assets in a table. The probability for joint returns is included in the table. For observing, you will have as much time as you want to. On the next page, you should view a graph depicting the joint returns of asset 1 and 2 in a simulation 1 (out of 60). In case you don't see a graph, please copy the link in your browser and try an alternative browser (e.g., Mozilla Firefox, Google Chrome or Safari) in order to participate in the experiment.

Subsequently, you are asked to split your fictive wealth of €10,000 between the two assets. Your compensation at the end of the experiment depends on this investment decision and newly simulated returns of both assets.

Screen 6 (Presentation of Return Distribution):

[Participants view the information on joint returns of the two assets in the respective presentation format they are randomly allocated to. Participants determine themselves how long to view each return pair (experience sampling treatments) or the frequency table of return pairs (description treatment) and click 'Continue' to continue. They cannot go back to previous screens after clicking 'Continue'.]

Screens 7 (Investment Decision):

You have €10,000 at your disposal. Your task is to split this wealth between the two assets. How much do you want to invest in asset 1, how much in asset 2? (Note: The two investments have to add up to €10,000.)

Investment in asset 1 (in €):
Investment in asset 2 (in €):

Screen 8 (Investment Decision):

Please describe briefly why you chose this allocation:

[This question is asked on round 1 only]

Screen 9 (Investment Decision):

In the following, we would like to ask you some questions about the reasons for the choice you made. Please select a category between 1 ('not at all') and 7 ('fully applies')

- 'I listened to my gut feeling' (Answer: '1' to '7'.)
- 'Which of the following statements describes the assets best?' (Answer: Asset 1 was riskier than asset 2. Asset 2 was riskier than asset 1. Both assets were similar risky. I did not think about this.)
- 'I like the investment in asset 2, because asset 2 often has high returns, once asset 1 has low returns, such that losses are compensated.' (Answer: '1' to '7'.)
- 'I like the investment in asset 2, because asset 2 often has high returns, once asset 1 has high returns, such that chances for high returns increase.' (Answer: '1' to '7'.)
- 'Overall, I think the risk-return-relationship of my allocation is exactly right.' (Answer: '1' to '7'.)

Elicitation of Beliefs:

Screen 10 (Dependence):

- 'Assets 1 and 2 move ...' (Five radio buttons from 'in opposite directions' to 'together'.)
- 'Given that asset 1's price decreases, I expect asset 2 to...' (Three radio buttons from 'decrease' to 'increase'.)
- 'Given that asset 1's price increases, I expect asset 2 to...' (Three radio buttons from 'decrease' to 'increase'.)
- 'Given that asset 1's price decreases, I expect asset 2's price to increase in ... out of 100 cases.' (Any numerical answer from 0 to 100 was allowed.)
- 'Given that asset 1's price increases, I expect asset 2's price to increase in ... out of 100 cases.' (Any numerical answer from 0 to 100 was allowed.)

Screen 11 (Portfolio Characteristics):

- 'Given your investment decision, what do you expect your portfolio value to be in one year?' (Any numerical answer ≥ 0 was allowed.)

- 'In how many out of 100 cases do you expect to lose money (a final portfolio value of less than €10,000 in one year)?' (Any numerical answer between 0 and 100 was allowed.)
- 'In how many out of 100 cases do you expect your final portfolio value to be more than €12,000 in one year?' (Any numerical answer between 0 and 100 was allowed.)
- 'In how many out of 100 cases do you expect your final portfolio value to be less than €8,000 in one year?' (Any numerical answer between 0 and 100 was allowed.)
- 'How risky do you perceive your portfolio to be?' (Seven radio buttons from 'risk-free' to 'very risky'.)
- 'How confident are you about your investment decision?' (Seven radio buttons from 'not confident at all' to 'very confident'.)
- 'How informed do you feel when making this investment decision?' (Seven radio buttons from 'not at all informed' to 'completely informed'.)

Round 2:

Screen 12 (Investment Decision 2 out of 2):

Round 2 of the Experiment start now. On the following screens, you will again be informed about the returns of two new assets. Subsequently, you are asked to split your fictive wealth of €10,000 between the two assets. You can invest your entire wealth into one of the two assets or split it up between the two assets as desired.

Screens 13-16: Round 2 of the Experiment, Repetition of Screens 6, 7, 10 and 11:

Survey:

Screen 17 (Basic Characteristics):

- Self-reported: 'Please estimate your willingness to take financial risk.' (Five radio buttons from 'not willing to accept any risk' to 'willing to accept substantial risk to potentially earn a greater return'.)
- 'How would you describe your knowledge about statistics?' (Four radio buttons from 'good' to 'bad'.)

- 'How would you evaluate the following statement (1='totally disagree', 6='fully agree'): I do not like thinking about issues that include numbers'(Answer: '1' to '6'.)
- 'How would you evaluate the following statement (1='totally disagree', 6='fully agree') 'I think it is important to to learn the interpretation of numerical information in order to make good decisions' (Answer: '1' to '6'.)
- Psychologists have established that different ways to compose a message with the same content influence the behavior of the receiver differently. This means that the opinion and perception of humans are susceptible by minor changes of wording. People do, for example, rather buy a product labelled '98% free of grease' as compared to '"2% fat content' How susceptible are you for such effects? (Answer: '1' to '6'.)
- 'How susceptible is the average participant of this experiment for this effect?' (Seven radio buttons from 'low' to 'high'.)

Screen 18 (Financial Literacy I):

- When an investor spreads his money among different assets, does the risk of losing a lot of money:
  - Increase
  - *Decrease*
  - Stay the same
  - Don't know
  - Refuse to answer

  (Item (5) from Fernandes, Lynch, and Netemeyer (2014).)
- Do you think that the following statement is true or false? 'Returns of single stocks are less volatile than returns of stock funds'
  - True
  - *False*
  - Don't know
  - Refuse to answer

Screen 19 (Financial Literacy I):

'You can select either one of two stock portfolios A and B. Portfolio A is worth €10,000 and fully invested in a randomly selected firm out of the 30 firms in the German stock index DAX. Portfolio B is worth €10,000 and equally divides the investment across the 30 firms in the German stock index DAX.'

- 'For which portfolio do you expect a higher return?' (Answer: A, B, or same return.)
- 'For which portfolio do you expect a higher risk?' (Answer: A, B, or same risk.)

Screen 20 (Lottery):

Thank you for participating in this experiment. Round i was selected or your payment and the simulation resulted in an annual return of X% for asset 1 and Y% for asset 2. Based on your allocation in round 1 your wealth would be XXX resulting in potential payment of XXX/1,000 = XX. This will be paid with an Amazon gift card. In case you get a performance based payment (every 10th participant) you will receive this amount of XX. If not, you will receive a Amazon gift card valued five Euros.

In case you would like to receive a gift card, please provide us with your email address:

- 'How satisfied are you with the result?' (Answer: 1-7)