How to Alleviate Correlation Neglect in Investment Decisions

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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 the probabilities for outcomes of the joint return distribution, we confirm the findings of others that investors neglect the correlation between assets in their diversification choices. However, when participants sample from the joint distribution, they change their allocation between two assets in response to a change in their correlation in the predicted direction. The results are robust across two experiments that have participants with varying experience (students vs. private investors).

Keywords: Investment Decisions, Diversification, Correlation Neglect, Risk Taking, FinTech.
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. We study how presentation formats for return distributions affect investors’ diversification choices. In particular, we analyze whether sampling returns instead of directly receiving probabilities of joint returns 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. In contrast, descriptions of probabilities for outcomes of the same joint return distribution result in correlation neglect, in line with experimental studies on diversification choice [Kroll et al. 1988]. The experimental designs in these studies overwhelmingly use descriptive presentation formats. Thus, our findings suggest that the results of previous studies might be induced by the design choice. We find an alleviation of correlation neglect as a response to sampling information in a controlled laboratory experiment with a student sample, as well as in an online experiment with a heterogeneous group of actual investors with varying expertise.

Why should investors care about correlations at all? Diversification is often called “the only free lunch in investment” and is the concept of investing in many assets to remove the idiosyncratic risk embedded in each to achieve a portfolio on the efficient frontier. This means that investors need to incorporate the correlation between assets into portfolio choice. In general, investors seem to have a hard time capturing diversification benefits. Investors take on more risk than necessary by holding underdiversified portfolios. They invest into few single stocks (an early finding that still holds, see Lehtinen and Keloharju 2015; Laudenbach et al. 2021) and concentrate their investments on employer stocks or other familiar assets, such as in their home or local market (e.g., Benartzi 2001; Grinblatt and Keloharju 2001). Such portfolios tend to be volatile and prone to crashes when investors are stressed 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. Furthermore, households do not only ignore correlations within their investment portfolio, but also between the portfolio and market states; a recent experimental study by Chinco et al. (2020) reveals correlation neglect when participants perform an allocation task while the correlation between consumption growth and stock returns varies.

We propose that sampling from joint return distributions alleviates correlation neglect in asset
allocation decisions. To derive our hypotheses, we build on findings for the effects of personal
experience on investors' risk taking. First, historical data indicate that risk perception and expec-
tations are influenced by experienced returns (e.g., Malmendier and Nagel, 2011). Second, studies
examining decision making show that experiences can also be generated artificially, which can be ef-
effectively used to inform investors about an asset’s risk-return profile. The idea is to enable investors
to experience a return distribution with the help of a sample of possible returns, e.g., through a
simulation. Providing participants with information about risk in an experience-based way has the
potential to increase the general understanding of risk and leads to more consistent investment
decisions (e.g., Kaufmann et al. 2013; Bradbury et al. 2015). Last, recent studies from psychol-
ogy on the human brain as a “natural sampler” reconcile the difficulty of humans when answering
simple questions about probabilities with behavior as if they are Bayesian learners (Sanborn and
Chater, 2016). Hence, generating an artificial experience of correlation is a promising—and so far
unexamined—tool to help investors diversify better.

To test this idea, we run two main experiments, Experiment 1 and 2, that differ in the heterogeneity
of participants. In both experiments, we vary correlation in a counterbalanced within-subjects
design and employ two different presentation formats (treatments) between subjects. For our de-
scription treatment, participants are shown all potential joint return states of two assets (Asset
1 and Asset 2), as well as their respective frequency of occurrence. For our experience sampling
treatment, we use an experience-based sampling procedure to inform participants. That is, they
are shown draws of joint returns of the two assets based on the underlying distribution.

For the diversification decision, participants have to allocate an endowment between two assets
in two investment rounds. Assets are positively correlated in one round, and negatively correlated
in the other, keeping everything else equal. In particular, marginal distributions do not change
between the (counterbalanced) correlation conditions, so that only changes in dependence across
assets can explain the treatment effects. Assets 1 and 2 are constructed so that Asset 2 should only
be selected due to its diversification potential.

We find that experience sampling as opposed to a description of correlations alleviates correlation
neglect in asset allocation decisions. In Experiment 1, participants in our description treatment
invest 6.23% (2.06 percentage points) less into the diversification asset (Asset 2) when diversification
benefits are larger, a portfolio choice that is inconsistent with expected utility theory at any level of
risk aversion. In contrast, participants in the experience sampling treatment invest 32.87% (10.62
percentage points) more into the diversification asset when diversification benefits are larger, which
is consistent with a relative risk aversion of around 4. We find that participants’ beliefs about
dependence between the two assets tend to be more accurate after experience sampling, compared
to the description treatment, which we assess through verballs statements like “if Asset 1 increases,
I expect Asset 2 to increase in ... out of 100 cases.” However, the effect of presentation formats
on diversification choices is not driven by a better understanding of risk at the portfolio level, as
beliefs about the likelihood of a loss are insensitive to strong actual changes in the probability of
loss, even after sampling.

Our findings hold for a heterogeneous sample of real investors in Experiment 2. The results
are robust if we control for sampling error (if the average sampled correlation deviates from the
descriptive one), a potential recency or primacy bias (putting more weight on the last or first draws),
or differences in attention (higher minimum time needed for observing returns in the experience
sampling treatment). In a series of further robustness tests (additional experiments) included in
the online appendix, we find that our results hold (1) in a sample of participants from the UK and
the US instead of Germany and (2) when we vary the characteristics of the experimental design
(using a more complex joint return distribution, an alternative descriptive format, as well as using
a sampling procedure with numerical returns instead of graphical return bars).

Our study contributes to several strands of the literature. First, we contribute to the literature
on diversification choices suggesting that investors do not increase diversification when correlation
decreases (e.g., Eyster and Weizsäcker, 2016; Kallir and Sonsino, 2009; Kroll et al., 1988). Other
studies use more ecologically valid sampling formats to present information and find that partic-
ipants change diversification decisions in response to changes in dependence between returns. As
an illustration, Wunderlich et al. (2011) show that participants can incorporate correlations into
a variance minimization task in a resource management game after observing correlated outcomes
over time. In the financial context, Ungeheuer and Weber (2021) 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. We reconcile this experimental literature on investors’ diver-
sification choices with the literature on correlation neglect by identifying a key driver of differences
in results: sampling.

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. We hence add to the 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 or sampling (e.g., Becker et al., 2020).

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Third, we contribute to the literature on Fintech and financial education on the spot (e.g., D’Acunto et al., 2019; Fernandes et al., 2014) by providing a tool that can help investors incorporate correlation into investment choices. This is particularly important today as 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 et al. (2013) have already served as an impulse for real-world tools used by financial institutions.1 They could be enhanced to a two asset-case (e.g., by letting investors sample returns of their actual portfolio together with an asset they consider buying).

2 Experimental Setup and Hypotheses

We experimentally test the following hypotheses on the effects of presentation formats on investors’ diversification choices:

$H_1$: Investors do not diversify more when correlation decreases if asset returns are presented in a descriptive way (based on prior evidence on correlation neglect).

$H_2$: Investors diversify more when correlation decreases if asset returns are presented in an experience-based way (based on prior evidence on experience-based presentation formats).

Testing both hypotheses within the same experimental design allows us to directly confront previous results on correlation neglect ($H_1$) with our new results on experience-based presentation formats ($H_2$). To test these hypotheses, we start with an individual investment experiment with a student sample in a computerized laboratory (Experiment 1). To test the heterogeneity of our effects, we expand our findings with an online experiment with real investors (Experiment 2).

2.1 Experimental task

In both experiments, we ask participants to allocate an endowment of €10,000 between two risky assets: Asset 1 and Asset 2. To define the joint distribution of the two assets’ annual returns, we adapt the design in Ungeheuer and Weber (2021). Asset 1 has an average return of 5%, while

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Asset 2 offers an average return of 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.

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 between the two 
assets and about the risk 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, portfolio risk, as 
well as additional control variables, such as demographics.

2.2 Stimuli — Correlation

The two allocation choices differ only in the linear dependence between the two assets (counter-
balanced within-subject design). Correlation is 0.6 in the high correlation condition and -0.6 in the 
low correlation condition. Asset 1 and Asset 2 have four potential outcomes each (see Table 1).

Normatively, we would expect participants to diversify more once correlation decreases. Figure 1 
demonstrates the trade-off between risk and return and confirms that the low correlation condition 
has much more potential to reduce portfolio variance at any given allocation including both assets. 
Figure 2 shows the optimal investment in Asset 2 for an expected utility-maximizing investor with 
constant relative risk aversion (CRRA) at a relative risk aversion from 0.5 to 10. With a decrease 
in correlation from 0.6 to -0.6, the diversification potential of Asset 2 increases, as does the optimal 
investment in Asset 2.

2.3 Stimuli — Presentation format

In both experiments, participants are randomly assigned to either a description or an experience 
sampling format. In both treatments, returns are colored green if positive and red if negative, as 
is mostly done with real market data. Examples for both treatments are shown in Figure 3. To 
link our experiment to studies on correlation neglect, we use a description treatment, where we

2 A translated version of all instructions and questions from the original experimental instructions (in German) 
can be found in the Online Appendix

3 We choose 0.6 and -0.6 with reference to Ungeheuer and Weber (2021); we do not believe that a change in the 
exact magnitudes of the coefficients would change our results. Kroll et al. (1988) use coefficients of (+/-) 0.8, while 
Kallir and Sonsino (2009) expose participants to correlation coefficients of (+/-) 1/3 and 2/3.
communicate the riskiness of returns via probability statements comparable to Kroll et al. (1988) or Kallir and Sonsino (2009). 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 experience treatment, participants are instead given information through an experience sampling procedure. More specifically, they have to make 60 draws of joint returns of Assets 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). We use a design based on Kaufmann et al. (2013), where the returns of both assets are presented graphically with two bars in one graph. We tested various variations to our design, which we will describe in the robustness section. Given that participants do not draw a representative sample of 100 return pairs, but make only 60 draws (without replacement) from that distribution, the sampled observations differ by participant and decision round. We control for such sampling error in our analysis.

2.4 Beliefs and additional control variables

To test whether participants ignore correlations or simply misunderstand them, we ask them about their perception of the frequency of comovement (“if Asset 1 increases, I expect Asset 2 to increase in ... out of 100 cases”). At the end of the experiment, participants are asked for demographics like gender, age, background in statistics and finance, as well as their self-assessed risk aversion. We also ask twelve financial literacy questions from Fernandes et al. (2014) and the four numeracy questions from Cokely et al. (2012). In Experiment 2, the experiment with actual investors, we enrich the data set with questions on real investment behavior and attitudes (e.g., participants’ trading frequencies or their interest in financial markets).

2.5 Payment

Participants are paid in an incentive-compatible manner. In the laboratory experiment, 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 by the shares of the €10,000

4Sampling without replacement reduces sampling error compared to sampling with replacement. In our robustness test with US/UK investors (see Section A.3 in the online appendix), we draw the full representative sample of 100 return pairs without replacement, so that the sampling error is reduced to zero.

5For robustness, we also ask questions about general dependence (e.g., “Asset 1 and Asset 2 move together / in opposite directions”; “if Asset 1 increases, I expect Asset 2 to increase / decrease”). Results based on these alternative questions are similar to the results based on the perceived frequency of comovement and available upon request.
endowment the participant allocated to the respective assets and divided by 1,000. Example: If a participant invests 70% in Asset 1 and 30% in Asset 2 in round 1 and the random draw revealed round 1 with a return of -5% for Asset 1 and 14% for Asset 2, her payment is: 

\[(0.7*10,000*(1-0.05)+0.3*10,000*(1+0.14))/1,000=\text{€10.07}.\]

Participants on average received a payoff of around €10 for a one-hour experiment session including instructions and payment. In the experiment with real investors, every participant was given a €5 Amazon voucher. Every 10th 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.

3 Baseline Results

3.1 Data and participants

Experiment 1 was conducted with 190 participants in May 2016 at the Frankfurt Laboratory for Experimental Economic Research (Goethe University Frankfurt). The software packages Orsee (Greiner 2003) and z-Tree (Fischbacher 2007) were used to conduct the experiment. The participant pool consists mainly of university students. Participants are on average 22 years old, 48% are male, and 52% are female. They have a decent financial knowledge (mean of 7 correct answers out of 12 financial literacy questions), report a moderate willingness to take financial risks (mean of 2.63 on a 1-5 scale with 5 referring to a high willingness), and 22% actually own equity. 72% of subjects have taken a statistics course, so that the majority should be familiar with the concept of correlations, although we never mention the word “correlation” in our experiments. Between the two treatments (description versus experience sampling), participants are balanced (no statistically significant differences).

3.2 Asset allocation decisions

Table 2 reports the share invested in Asset 2 by treatment and condition. In line with correlation neglect \((H_1)\), we find that participants invest on average a similar amount in Asset 2 in the high (33.08%) correlation condition as compared to the low (31.02%) correlation condition. In contrast, participants allocate on average 10.62 percentage points less to Asset 2 in response to correlation changes from low to high in the experience sampling treatment, in line with experience sampling alleviating correlation neglect \((H_2)\). Comparing these two differences shows that the degree of diversification in response to correlation-changes increases significantly from description to experience.
sampling ($t$-stat = 3.62). The results hold in a random effects regression framework with the share invested in Asset 2 as the dependent variable. Specification (1) in Panel A of Table 3 confirms our previous results. Participants invest an average of 31% into Asset 2 in the description treatment in the low correlation condition. For participants in the sampling treatment this share significantly increases with a change from high to low correlations. For robustness, we exclude participants who might not have understood the general diversification potential of Asset 2. Results in Specification (2) show that our results are robust to the exclusion of participants who invest more than 50% in Asset 2. Next, we show that our results hold when we restrict our sample to participants’ first decision only (Specification (3)). Every participant in our experiments has to make two investment choices: one in the low correlation condition, and one in the high correlation condition. One could argue that the second decision is influenced by the first. This does not drive our results. The effect of presentation formats is hence present in a pure between-subjects design. Still, 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 (Second Decision), as well as the interaction between the second-round dummy and the correlation dummy (Learning). Both of these coefficients are statistically insignificant and economically close to zero. We thus do not find that the participants exhibit a learning effect. This is in line with the results of [Kroll et al. (1988)], who also do not find a session-to-session change in allocation.

Do our results imply that sampling leads to a normative improvement in portfolio choice? Due to the randomized allocation of participants to presentation formats, there is no systematic variation in risk aversion between the description and the sampling format. Other features of the investment decision (including incentivization) are also independent of the presentation format treatment. Under constant relative risk aversion and for typical values of relative risk aversion around four, we would expect an increase in Asset 2’s weight from around 30% to around 45% from the high-to the low-correlation condition (see Figure 2). This is very close to what we observe on average in the experience sampling treatment (see Table 2). In contrast, the correlation-insensitive (but significantly larger-than-zero) weight of Asset 2 in the description treatment cannot be reconciled with an optimal investment choice at any level of constant relative risk aversion (CRRA). Hence, the sampling treatment makes average investment choices more consistent with CRRA preferences.

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6Estimates of relative risk aversion in the literature are typically at around four and range from below one to eight (Friend and Blume 1975; Metrick 1995; Kimball et al. 2008; Aarbu and Schroyen 2018; Paravisini et al. 2017).
3.3 Robustness tests: Sampling error, recency bias, attention, and alternative designs

Fox and Hadar (2006) suggest 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 in the experience sampling treatment either put more weight on the correlations observed in the last draws (recency) or if the average correlation observed in the 60 draws deviates from the descriptive one (sampling error). Therefore, we test whether the realized correlations of return-pairs (first, last, as well as the realized correlation after all 60 draws) have an effect on our result. For the following analyses, we exclude participants in the description treatment, since it exhibits no variation in observed returns. For comparison, Specification (1) of Panel B of Table 3 reports the results on the high correlation coefficient for all subjects in the experience sampling treatment only. In Specifications (2) and (3), we include a dummy indicating whether the last (Specification (2)) or the first (Specification (3)) sampled return-pair’s correlation was positive. The results reveal that the effects of correlations experienced in the first or the last draw are weak and that participants still significantly respond to shifts in correlation after controlling for such primacy or recency effects.

Next, we test the role of sampling error. The average realized correlation in the experience sampling treatment is, as expected, -0.6 in the low correlation condition, and +0.6 in the high correlation condition. However, realized correlation has a between-subjects range of -0.3 to -0.8 and 0.3 to 0.8 from minimum to maximum realized correlations, respectively. In Specification (4) of Panel B of Table 3, we regress on the realized correlation instead of a high correlation condition dummy. We again find that a higher correlation is associated with an economically meaningfully lower share invested in the diversification Asset 2 (decrease of 8.8 percentage points per unit of realized correlation). In Specifications (5) and (6), we provide a sample split into stronger and weaker correlation stimuli by including only respondents with a realized correlation, that is larger than 0.6 and smaller than -0.6 in Specification (5) and smaller than 0.6 and larger than -0.6 in Specification (6). We find that the coefficients of the high correlation dummy are not significantly distinguishable across these two subsamples (F-test, Prob > chi^2 = 0.683), indicating that nonlinearities between realized correlation and the investment decision do not play a significant role.

\footnote{In an unreported test, we included participants in the description treatment and compared them to only those participants in the experience sampling treatment 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. The coefficient of the interaction term between sampling and the high correlation dummy is -0.11 and hence close to the baseline effect of -0.13 in...}
Overall, these robustness tests reveal that our main result is not driven by sampling error or non-linear treatment effects.

To react to a treatment, participants need to be attentive to the information provided. In our case, it could be that the effect of experience sampling on correlation neglect is at least partially influenced by the time needed to collect 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 treatment, as participants have to view one screen in the former treatment and 60 screens in the latter treatments. The average time spent in the experience sampling treatment is 106 seconds, which is significantly higher than the 75 seconds spent on average in the description treatment ($t$-stat = 4.91). The viewing times are similar across correlation conditions.

It is plausible that spending more time viewing the information might improve the diversification decision. Panel C of Table 3 shows the investment into Asset 2 split into 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 effect of sampling on correlation neglect in our sample.

Finally, we run a series of additional experiments to test the robustness of specific features of our baseline experiment. To keep the paper succinct, we describe and report these results in the online appendix only (see Appendix A). Overall, results are consistent with our main findings when we display returns in our experience sampling treatment numerically instead of depicting graphical return bars (see section A.1 in Appendix A). They also hold if we use a more complex joint return distribution (see section A.2 in Appendix A) or if we apply a matrix-like descriptive format instead of the baseline table (see section A.3 in Appendix A). Using an online platform (Prolific) in the last experiment, we are also able to confirm that our results hold in a sample of participants from the UK and the US.

### 3.4 Perceptions of dependence and portfolio risk

Panel A of Table 4 reports participants’ beliefs about the frequency of comovement (i.e., the frequency of same-signed return pairs). Correct answers are marked by boxes and are 20 for the low correlation condition and 80 for the high correlation condition. We find that participants move their answers in the right direction in response to correlation-changes in both treatments. The effect

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Specification (1) of Table 3 further supporting that sampling error does not drive our result.

*Note that this evidence is just indicative as viewing times are endogenous.*

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is, however, much smaller and significantly weaker in the description treatment. In the experience sampling treatment, participants clearly notice the shift in dependence and report an average comovement of 39.22% in the low correlation condition and 62.89% in the high correlation condition. In the description treatment, the beliefs only increase by 4 percentage points from the low (34.33) to high correlation (38.27) condition. In line with Matthies (2021), we find that participants generally underestimate dependence, but significantly more so 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. Overall, the effect size for the experience sampling treatment is around five to six times larger than the effect size for the description treatment, consistent with participants being able to form more accurate beliefs after sampling.

Next, we analyze whether participants accurately understand portfolio risk. Diversification is valuable because it typically reduces portfolio risk. Reinholtz et al. (2021) 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 between assets. Can participants properly use their knowledge about comovement to estimate overall portfolio risk? To find out, we ask participants to estimate the probability of a portfolio loss. Bradbury et al. (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 experiments, the frequency of losses cannot be directly observed. Participants need to combine their chosen portfolio weight with the joint return distribution of Assets 1 and 2 to estimate loss probabilities, which is a cognitively challenging task. We report the results for estimated versus true loss probabilities in Panel B of Table 4.

From an objective perspective, moving from one correlation condition to the other strongly affects the loss probability in participants’ portfolios. At a lower correlation, the likelihood of joint bad returns becomes smaller, so that portfolio-level losses become unlikely. For the description treatment, the true loss probability increases by over 17 percentage points from the low correlation condition to the high correlation condition. In the experience sampling group, the increase in true loss probability is even larger at over 24 percentage points, which is caused by the higher level of diversification in the sampling treatment under a lower correlation. However, participants’ estimates

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9 As mentioned earlier, we also assessed alternative questions for beliefs about dependence, for robustness. Results are comparable if we ask for downside (“if Asset 1 decreases, Asset 2 decreases in ... of 100 cases”) instead of upside comovement.
for the loss probability increase by less than 1 percentage point from the low to the high correlation condition and these increases are statistically insignificant, both after the description and the sampling treatment. Hence, we find that participants are not able to use their understanding of comovement to properly assess portfolio risk.\footnote{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.}

This result does not contradict our previous finding that correlation neglect is reduced when sampling is used as a presentation format. The results on the perception of dependence between assets clearly show that participants better understand dependence on a state-by-state basis in the sampling treatment. Their investment decisions in Table 2 are in line with this more accurate understanding of dependence. The misestimation of portfolio risk in Panel B of Table 4 just shows that participants on average are not able to aggregate state-by-state beliefs to the portfolio level. It is not necessary to perform the challenging task of aggregating individual asset return distributions to the portfolio’s return distribution \footnote{The recent literature from psychology on the human brain as a “Bayesian sampler” might provide a deeper understanding of the observation that people make choices like a Bayesian without consciously calculating or representing probabilities (e.g., Sanborn and Chater, 2010).} to react to changes in correlation. Understanding what happens to Asset 2 when Asset 1 decreases in value is enough for participants to grasp part of the value of diversification. Nevertheless, it is clear 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.\footnote{The recent literature from psychology on the human brain as a “Bayesian sampler” might provide a deeper understanding of the observation that people make choices like a Bayesian without consciously calculating or representing probabilities (e.g., Sanborn and Chater, 2010).}

4 Heterogeneity of Treatment Effects

In Experiment 2, we test the stability of our baseline results from Experiment 1 for a sample of actual investors in an online 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 305 participants. Experiment 2 was programmed and conducted with oTree \footnote{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.} (Chen et al., 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 news
section of large German newspapers and participants indicated that they are willing to participate
in future studies. We sent out invitations to all participants on the list and ended up with a
response rate of 7.4% (142 participants in the description and 163 participants in the experience
sampling treatment). Given the recruitment process, our sample may not be representative of the
German population or even for the average German investor. The intention of this experiment 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, which varies substantially in personal
and investment characteristics. 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 (91%),
trades at least once a year, and reports a median wealth of at least €100,000. The willingness to
take financial risk is higher in this group as compared to the student sample (3.42 vs 2.63). With
regard to the experimental randomization, we do not observe any statistically significant differences
in personal characteristics between the two treatments.

4.2 Asset allocation decisions

Consistent with the results for Experiment 1, we find that participants on average diversify less
in the high correlation condition than the low correlation condition, as is optimal for a risk-averse
investor, see Table 5. The effect is again statistically significant between the high and low correlation
conditions in the experience sampling treatment ($H_2$) and we do not find significantly different
allocations between the correlation stimuli in the description treatment ($H_1$). More precisely,
participants allocate on average 14.87 percentage points less in Asset 2 in response to correlation
changes in the experience sampling treatment, while the difference is 1.88 percentage points in the
description treatment. Looking at participants’ allocations in our difference-in-difference design,
we find that the degree of diversification in response to correlation changes increases significantly,
by 12.99 percentage points, from the description to the experience sampling treatment ($t$-stat =
4.41).

In Figure 4, we summarize the average investment shares in diversification Asset 2 for the high

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12 Nineteen percent of all invited participants clicked on the link. If we analyze attrition in more detail, we find
that attrition is lower in the experience sampling treatment: It is 57% in the sampling treatment versus 63% in the
description treatment. Forty-seven percent of participants who drop out do this on the introductory and instruction
pages, while 27% depart the study in the information presentation stage.
correlation condition and the low correlation condition by treatment for different subsamples of participants (e.g., differences in wealth, experience, sophistication or patience). The construction of the subsamples of participants is described in detail in the figure notes and new variables are defined in Table 6. In this discussion, we focus mostly on the stability of our results across all subsamples. The bars in the experience sampling treatment (Panel B) reveal that allocations to the diversification Asset 2 increase significantly with a decrease in correlation across all, even quite small, subsamples. When we look at the subsamples in the descriptive treatment (Panel A), we find a statistically significant effect for one subgroup only, namely for participants who mistakenly think that diversification via combining randomly selected Dow Jones stocks increases expected returns. This difference is nevertheless much weaker than differences in the experience sampling treatment. In general, differences in economic magnitudes across treatments can be recognized at first glance, with hardly discernible effects in the description treatment and clear effects in the experience sampling. It might be surprising that even subsamples of participants that have trading experience or 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 sampling of returns robustly alleviates correlation neglect, in line with $H_1$ and $H_2$.

### 4.3 Perceptions of dependence and risk

The heterogeneous subject pool in Experiment 2 also gives us the opportunity to analyze whether the influence of the presentation format on the perception of comovement is stable or interacts with participant characteristics. The first two bars in Panel A versus Panel B of Figure 5 for the overall sample reveal that perceptions of comovement again move much more strongly with an increase in correlation in the experience sampling as compared to the description treatment. Panels A and B of Figure 5 generally reveal similar patterns as in Experiment 1. Almost all participants note an increase in the frequency of comovement from the low correlation condition to the high correlation condition, but the effect is much smaller in the description treatment, even if statistically significant.

With regard to the perception of portfolio risk, we again find in Experiment 2 that participants are unable to use their more accurate understanding of correlations after sampling to properly
assess the probability of loss. Their estimates of the probability of a loss are almost the same in both the low and the high correlation condition in both treatments.

5 Conclusion

In this study, we show experimentally that using an experience sampling procedure helps investors diversify more when the correlations between two assets are lower and diversification benefits are higher. Even though participants do not seem to revise their beliefs about the portfolio variance as standard portfolio theory would suggest, their behavior is more in line with normative portfolio choice theory (Markowitz 1952). Our findings are robust across different subsets of real investors.

Our 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.

More accurate beliefs about correlation after sampling may be one driver given that beliefs about correlation significantly improve from the description to the sampling treatment in both experiments. Alternatively, sampling might lead investors to have a stronger focus on diversification benefits (i.e., a stronger preference to diversify away large changes in portfolio value). We do, however, find that the effect of presentation formats on diversification choices is not driven by a better understanding of risk at the portfolio level. Hence, we speculate that investors instead evaluate diversification benefits on a state-by-state basis (e.g., “Asset 2 frequently 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 (2021), who find that participants diversify as if using a counting heuristic for up and down states in their perception of dependence, instead of optimizing portfolio return distributions under observed correlations.

Assuming that the incorporation of diversification benefits into portfolio choice makes investors better off, our study has implications for regulators, financial institutions, investment advisors, and fintech firms. For example, 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

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documents in the European Union).

Of course, informing clients with the help of experience sampling may be a little more time-consuming than simply providing a descriptive fact sheet. Would real investors be willing to spend that time? Evidence suggests that they would be willing. If we look at attrition rates in Experiment 2, our online experiment with actual investors, we find that participants are at least as likely to complete the more time consuming sampling procedure as the quick, descriptive presentation procedure, despite the low stakes compared to an actual investment decision. Aside from that, information tools in finance are widely used. Consumers are willing to spend time using them, without being paid, and seem to enjoy getting informed about investing more generally.

How could sampling tools be incorporated into diversification decisions? Many banks, investment firms, and especially fintech start-up firms are already using a portfolio-based allocation approach. They also offer decision-making tools on their websites and in their applications (including “add comparison” or “compare to” tools to expand the number of assets in price charts). Effective sampling procedures like the ones successfully tested in our experiments can be incorporated into such tools. This would not mean that investors in a real-world setting, who choose between a practically infinite number of financial assets, would need a tool that allows to sample all possible assets jointly. Investors could rather sample returns of their current portfolio together with the returns of assets they consider buying, like local and international index funds, or single stocks from their home country and beyond. As an illustration, a US investor might sample the returns of a currently held S&P 500 index fund together with an Emerging Markets index fund. Additionally, an educational tool based on sampling different correlation patterns could explain the concept of diversification in a playful way in the spirit of the boosting literature (e.g., [Hertwig](#) 2017).

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13 In the last couple of years, personal finance books (“The Automatic Millionaire,” “Start Late,” Finish Rich,” “The Total Money Makeover,” and “Nudge”) were among the general *New York Times* bestseller list with more than one million copies sold each. There are also podcasts that inform about personal finance, which are widely listened to. For instance, one of the most popular personal finance podcast (“The Dave Ramsey Show”) has 14 million listeners. The well-known “The Tim Ferriss Show” is the No. 1 business podcast on Apple Podcasts, has surpassed 500 million downloads and has also been named as the top business podcast by readers of Fortune Magazine’s Term Sheet. Also in line with an increase in public attention towards portfolio management, [Ungeheuer and Weber](#) (2021) report an increase over the last fifty years in the percentage of *New York Times* articles containing words related to diversification and portfolio risk management.
References


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Figure 1: 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: 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. The low- and high-correlation conditions 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 and 2. Panel A shows the information presented in the description treatment for low (left-hand side) and high (right-hand side) correlation conditions. Panel B depicts an example screen from the experience sampling treatment. 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 were displayed to participants in green (red) when positive (negative).

Panel A: Description Treatment

<table>
<thead>
<tr>
<th>return (% per year)</th>
<th>expected in ... of 100 cases</th>
<th>return (% per year)</th>
<th>expected in ... of 100 cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asset 1</td>
<td>Asset 2</td>
<td>Asset 1</td>
<td>Asset 2</td>
</tr>
<tr>
<td>-25%</td>
<td>-26%</td>
<td>-25%</td>
<td>-26%</td>
</tr>
<tr>
<td>-25%</td>
<td>34%</td>
<td>-25%</td>
<td>34%</td>
</tr>
<tr>
<td>-5%</td>
<td>-6%</td>
<td>-5%</td>
<td>-6%</td>
</tr>
<tr>
<td>-5%</td>
<td>14%</td>
<td>-5%</td>
<td>14%</td>
</tr>
<tr>
<td>15%</td>
<td>-6%</td>
<td>15%</td>
<td>-6%</td>
</tr>
<tr>
<td>15%</td>
<td>14%</td>
<td>15%</td>
<td>14%</td>
</tr>
<tr>
<td>35%</td>
<td>-26%</td>
<td>35%</td>
<td>-26%</td>
</tr>
<tr>
<td>35%</td>
<td>34%</td>
<td>35%</td>
<td>34%</td>
</tr>
</tbody>
</table>

Panel B: Experience Sampling Treatment
Figure 4: Experiment 2: Cross-Sectional Variation in Diversification Choice

This figure shows the average investment in Asset 2 by correlation condition (low and high) and presentation format treatment (description in Panel A and sampling in Panel B) for subsamples of participants in Experiment 2. For each pair of bars, the dark, left-hand side (light, right-hand side) bar is the average investment in Asset 2 in the low-correlation (high-correlation) condition. The subgroups are displayed below each pair of bars, with the number of observations on the round-level in parentheses ($N$) and */**/*** indicating statistical significance based on random effect regressions of the difference between low and high correlation at the 10%, 5%, and 1% levels respectively. For the first subsample, female participants are carved out. The second subsample consists of participants above 50 years in age. High wealth carves out investors who report a wealth (excluding real estate) of more than 100,000 euros. Further, we use additional splitting variables on trading behavior and personal traits that are defined in Table 6.

Panel A: Description Treatment

Panel B: Experience Sampling Treatment
Figure 5: Experiment 2: Cross-Sectional Variation in Perceptions of Dependence

This figure shows the average perceived frequency of comovement between Asset 1 and Asset 2 by correlation condition (low and high) and presentation format treatment (description in Panel A and sampling in Panel B) for subsamples of participants in Experiment 2. Perceptions of the frequency of comovement are based on the question “If Asset 1 increases, I expect Asset 2 to increase in ... out of 100 cases.” For the first subsample, female participants are carved out. The second subsample consists of participants above 50 years in age. High wealth carves out investors who report a wealth (excluding real estate) of more than 100,000 euros. Further, we use additional splitting variables on trading behavior and personal trait that are defined in Table 6.

Panel A: Description Treatment

Panel B: Experience Sampling Treatment
Table 1: Correlation Conditions

This table shows 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 \(-0.6\)

<table>
<thead>
<tr>
<th>return</th>
<th>-25%</th>
<th>-5%</th>
<th>15%</th>
<th>35%</th>
<th>sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>-26%</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
<td>4%</td>
<td>5%</td>
</tr>
<tr>
<td>-6%</td>
<td>0%</td>
<td>9%</td>
<td>36%</td>
<td>0%</td>
<td>45%</td>
</tr>
<tr>
<td>14%</td>
<td>0%</td>
<td>36%</td>
<td>9%</td>
<td>0%</td>
<td>45%</td>
</tr>
<tr>
<td>34%</td>
<td>4%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>5%</td>
</tr>
<tr>
<td>sum</td>
<td>5%</td>
<td>45%</td>
<td>45%</td>
<td>5%</td>
<td>100%</td>
</tr>
</tbody>
</table>

**High correlation condition:** Pearson-Correlation of \(+0.6\)

<table>
<thead>
<tr>
<th>return</th>
<th>-25%</th>
<th>-5%</th>
<th>15%</th>
<th>35%</th>
<th>sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>-26%</td>
<td>4%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>5%</td>
</tr>
<tr>
<td>-6%</td>
<td>0%</td>
<td>36%</td>
<td>9%</td>
<td>0%</td>
<td>45%</td>
</tr>
<tr>
<td>14%</td>
<td>0%</td>
<td>9%</td>
<td>36%</td>
<td>0%</td>
<td>45%</td>
</tr>
<tr>
<td>34%</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
<td>4%</td>
<td>5%</td>
</tr>
<tr>
<td>sum</td>
<td>5%</td>
<td>45%</td>
<td>45%</td>
<td>5%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 2: Experiment 1: Allocation into Diversification Asset 2

This table shows the average allocation to the diversification Asset 2 in % by condition (columns) and treatment (rows). \(t\)-stats are reported in parentheses. *//**/*** denote significance at the 10%, 5%, 1%-levels respectively.

<table>
<thead>
<tr>
<th>Description</th>
<th>Low Correlation</th>
<th>High Correlation</th>
<th>Difference</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience Sampling</td>
<td>31.02%</td>
<td>33.08%</td>
<td>2.06%</td>
<td>(0.88)</td>
</tr>
<tr>
<td>Difference</td>
<td>42.93%</td>
<td>32.31%</td>
<td>-10.62%***</td>
<td>(-3.62)</td>
</tr>
<tr>
<td>Difference</td>
<td>-12.68%***</td>
<td></td>
<td></td>
<td>(-3.62)</td>
</tr>
</tbody>
</table>

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Table 3: Experiment 1: Robustness Tests Asset Allocation

This table shows robustness tests for the results on asset allocations in Table 2. Panels A and B report the results of random effects regressions with \( \text{Share}_2 \), the investment in Asset 2 (as a portfolio weight between 0 and 1), as the dependent variable. Panel C shows average \( \text{Share}_2 \) by condition (columns) and treatment (rows), as in Table 2. Specifically, Specification (1) in Panel A shows results of our baseline regression, where the main variable of interest is the interaction term of the sampling treatment indicator (\text{Sampling}) and the high correlation condition indicator (\text{High Correlation}). In Specification (2), we exclude participants investing more than 50% in Asset 2. In Specification (3), we look at participants’ first decision only (pure between-subjects design). In Specification (4), we test for learning effects. In particular, \text{Second Decision} is an indicator variable, which equals one if the investment decision is from the second round of the experiment. \text{Learning} is an indicator variable that equals one if the investment decision is from the second round of the experiment and the participant samples from the high correlation return distribution. In Panel B, we consider various specifics of the actual sample drawn by participants in the experience sampling procedure. In Specification (1), as in all other specifications in this panel, we analyze the effect of experienced return histories and thus only include participants with variation in observed returns, i.e., participants in the sampling treatment. In Specifications (2) and (3), we include a dummy indicating whether the last (Column (2)) or the first (Column (3)) sampled return-pair’s correlation was positive. In Specification (4), we regress on the realized correlation instead of a high correlation condition dummy. In Specifications (5) and (6), we provide a sample split into stronger and weaker correlation stimuli by including only respondents with a realized correlation, that is larger than 0.6 and smaller than -0.6 in Specification (5) and smaller than 0.6 and larger than -0.6 in Specification (6). Panel C shows the average allocation to the diversification Asset 2 in % by condition (columns) and treatment (rows), like Table 2 but split into participants who spend below or above median time to view the information about the asset returns. Median splits were conducted between participants, based on each participant’s total viewing time of the presentation formats over both rounds. \( t \)-stats are reported in parentheses. */**/*** denote significance at the 10%, 5%, 1%-levels respectively.

<table>
<thead>
<tr>
<th></th>
<th>( \text{Share}_2 ) All</th>
<th>( \text{Share}_2 ) ( \leq 0.5 )</th>
<th>( \text{Share}_2 ) First Decision</th>
<th>( \text{Share}_2 ) All</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sampling x High Correlation</strong></td>
<td>-0.1268***</td>
<td>-0.0847***</td>
<td>-0.1447***</td>
<td>-0.1270***</td>
</tr>
<tr>
<td></td>
<td>(-3.62)</td>
<td>(-3.10)</td>
<td>(-2.71)</td>
<td>(-3.62)</td>
</tr>
<tr>
<td><strong>Sampling</strong></td>
<td>0.1190***</td>
<td>0.0872***</td>
<td>0.1165***</td>
<td>0.1191***</td>
</tr>
<tr>
<td></td>
<td>(4.19)</td>
<td>(3.54)</td>
<td>(3.15)</td>
<td>(4.18)</td>
</tr>
<tr>
<td><strong>High Correlation</strong></td>
<td>0.0206</td>
<td>0.0076</td>
<td>0.0340</td>
<td>0.0253</td>
</tr>
<tr>
<td></td>
<td>(0.85)</td>
<td>(0.41)</td>
<td>(0.92)</td>
<td>(0.76)</td>
</tr>
<tr>
<td><strong>Learning</strong></td>
<td>-0.0086</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.19)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Second Decision</strong></td>
<td>-0.0008</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.03)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>0.3102***</td>
<td>0.2701***</td>
<td>0.3118***</td>
<td>0.3106***</td>
</tr>
<tr>
<td></td>
<td>(15.70)</td>
<td>(16.47)</td>
<td>(12.25)</td>
<td>(12.99)</td>
</tr>
<tr>
<td><strong>Random Effects</strong></td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td><strong>No. obs.</strong></td>
<td>380</td>
<td>326</td>
<td>190</td>
<td>380</td>
</tr>
</tbody>
</table>
Table 3 (continued): Experiment 1: Robustness Tests Asset Allocation

Panel B: Recency Effects, Primacy Effects, Sampling Errors, and Non-Linearities

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Last Corr. High</td>
<td>-0.0053</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.15)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Corr. High</td>
<td></td>
<td>-0.0540</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-1.47)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Realized Correlation</td>
<td></td>
<td></td>
<td>-0.0877***</td>
<td>-0.0832***</td>
<td>-0.0932***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-4.11)</td>
<td>(-2.78)</td>
<td>(-2.62)</td>
</tr>
<tr>
<td>High Correlation</td>
<td>-0.1062***</td>
<td>-0.1029***</td>
<td>-0.0710**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-4.05)</td>
<td>(-2.96)</td>
<td>(-2.01)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.4293***</td>
<td>0.4303***</td>
<td>0.4386***</td>
<td>0.3757***</td>
<td>0.3792***</td>
</tr>
<tr>
<td></td>
<td>(21.38)</td>
<td>(20.17)</td>
<td>(20.85)</td>
<td>(24.68)</td>
<td>(17.93)</td>
</tr>
<tr>
<td>Random Effects</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>No. obs.</td>
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<td>184</td>
<td>184</td>
<td>184</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>95</td>
</tr>
</tbody>
</table>

Panel C: Attention Paid and Asset Allocation

<table>
<thead>
<tr>
<th></th>
<th>Low Correlation</th>
<th>High Correlation</th>
<th>Difference</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>32.14%</td>
<td>31.37%</td>
<td>-0.78%</td>
<td>(-0.21)</td>
</tr>
<tr>
<td>Experience Sampling</td>
<td>41.96%</td>
<td>31.30%</td>
<td>-10.65%**</td>
<td>(-2.54)</td>
</tr>
<tr>
<td>Total Time &gt; Median</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>29.90%</td>
<td>34.80%</td>
<td>4.90%</td>
<td>(1.15)</td>
</tr>
<tr>
<td>Experience Sampling</td>
<td>43.89%</td>
<td>33.31%</td>
<td>-10.59%***</td>
<td>(-2.74)</td>
</tr>
</tbody>
</table>

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Table 4: Experiment 1: Perceptions of Dependence and Risk

This table reports results for participants’ perception of dependence between assets 1 and 2 (Panel A) and participants’ assessment of portfolio risk (Panel B). Specifically, Panel A shows the number of responses within each answer-category of participants’ perception of the frequency of co-movement between Asset 1 and Asset 2. All answers are shown by treatment and condition. Boxes around numbers indicate true values. The bottom rows show the mean responses, as well as differences (between the high- and low-correlation conditions) and the difference-in-difference (between the description and sampling treatment). Panel B shows the average frequency of losses on the portfolio level, as assessed by participants (“Average Estimate”) and as actually sampled (“Average True Value”). t-stats are reported in parentheses. */**/*** denote significance at the 10%, 5%, 1%-levels respectively.

### Panel A (Frequency of Upside Comovement):
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.)

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[0,20)</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>(20,40)</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>(40,60)</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>(60,80)</td>
</tr>
<tr>
<td>80</td>
</tr>
<tr>
<td>(80,100]</td>
</tr>
<tr>
<td>mean</td>
</tr>
<tr>
<td>- low correlation</td>
</tr>
<tr>
<td>Diff. in Diff.</td>
</tr>
</tbody>
</table>

### Panel B (Estimation of expected "loss cases" and true values):
I expect my portfolio to experience a loss in ... out of 100 cases.
(Any answer from 0 to 100 was allowed.)

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Estimate</td>
</tr>
<tr>
<td>Description</td>
</tr>
<tr>
<td>Experience Sampling</td>
</tr>
<tr>
<td>Average True Value</td>
</tr>
<tr>
<td>Description</td>
</tr>
<tr>
<td>Experience Sampling</td>
</tr>
</tbody>
</table>
Table 5: Experiment 2: Allocation into Diversification Asset 2

This table shows the average allocation into the diversification Asset 2 in % by condition (columns) and treatment (rows). t-stats are reported in parentheses. */**/*** denote significance at the 10%, 5%, 1%-levels respectively.

<table>
<thead>
<tr>
<th>Description</th>
<th>Low Correlation</th>
<th>High Correlation</th>
<th>Difference</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>29.66%</td>
<td>27.78%</td>
<td>-1.88%</td>
<td>(-0.95)</td>
</tr>
<tr>
<td>Experience Sampling</td>
<td>38.33%</td>
<td>23.46%</td>
<td>-14.87%***</td>
<td>(-6.94)</td>
</tr>
</tbody>
</table>

Table 6: Variable Descriptions

This table reports variable descriptions. For the exact question, see Section B of the online appendix.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investor</td>
<td>Participant who report to own stocks or an equity mutual fund.</td>
</tr>
<tr>
<td>Frequent trader</td>
<td>Participants who claim to trade more frequently than every 4-12 months.</td>
</tr>
<tr>
<td>Risk-averse</td>
<td>Participant who are categorized below-median according to self-assessed</td>
</tr>
<tr>
<td></td>
<td>willingness to take risks in the sample.</td>
</tr>
<tr>
<td>Div. risks</td>
<td>Participant who correctly state that diversification decreases risk.</td>
</tr>
<tr>
<td>Div. return</td>
<td>Participant who correctly state that diversification (combining randomly</td>
</tr>
<tr>
<td></td>
<td>selected stocks from the Dow Jones) does not increase return expectations.</td>
</tr>
<tr>
<td>Susceptibility</td>
<td>Participant who classify themselves as less susceptible to framing than the</td>
</tr>
<tr>
<td></td>
<td>average participant based on an example that we give in the survey.</td>
</tr>
<tr>
<td>Patient</td>
<td>Dummy equal to 1 if a participant classifies herself as above-median on</td>
</tr>
<tr>
<td></td>
<td>self-assessed patience.</td>
</tr>
<tr>
<td>Numbers important</td>
<td>Participants reporting an above-median score to the statement “I think it</td>
</tr>
<tr>
<td></td>
<td>is important to to learn the interpretation of numerical information in</td>
</tr>
<tr>
<td></td>
<td>order to make good decisions.”</td>
</tr>
<tr>
<td>Dislike numbers</td>
<td>Dummy equal to 1 if a participant reports an above-median score to the</td>
</tr>
<tr>
<td></td>
<td>question “I do not like thinking about issues that include numbers.”</td>
</tr>
<tr>
<td>Knows statistics</td>
<td>Dummy equal to 1 if a participant reports an above-median self assessment</td>
</tr>
<tr>
<td></td>
<td>to “How would you describe your knowledge about statistics?”</td>
</tr>
<tr>
<td>Low Fin Literacy</td>
<td>Participants answering none of the financial literacy questions on</td>
</tr>
<tr>
<td></td>
<td>diversification (see Fernandes et al. 2014) correctly.</td>
</tr>
</tbody>
</table>
Online Appendix
Robustness Experiments and Experimental Instructions/Questions for:
“How to Alleviate Correlation Neglect in Investment Decisions”

Christine Laudenbach\textsuperscript{1}  Michael Ungeheuer\textsuperscript{2}  Martin Weber\textsuperscript{3}

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\textsuperscript{2}Michael Ungeheuer: Department of Finance, Aalto University, E-mail: michael.ungeheuer@aalto.fi
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A Additional Experiments

A.1 Numerical Sampling

Compared to the description treatment, the experience sampling treatment not only varies by letting participants sample from the joint return distribution, but also by providing graphical return bars instead of numerical returns. To understand, which component of our treatment drives our results, we use a numerical experience sampling design as an alternative to graphical sampling in a robustness test. In line with Hertwig et al. (2004), we express the returns of both assets in numerical outcomes in this condition (e.g., 15% for Asset 1 and −6% for Asset 2, see Figure A1 for an example). To ensure the robustness of our main results, this alternative treatment was tested as an additional treatment in Experiment 1 at the Frankfurt Laboratory for Experimental Economic Research.

Figure A1: Presentation Format (Numerical Experience Sampling)

This exhibit illustrates the information shown to participants in an alternative sampling presentation format, with numerical instead of graphical return information. 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.

The numerical sampling group comprises 98 participants and demographic characteristics are in line with the other participants in Experiment 1 (mean age of 22.36, share of females 50%). In Table A1, we compare the results for the numerical experience sampling group to the results in the description group (Experiment 1). Participants allocate on average 7.37% less in Asset 2 in response to correlation changes in the numerical sampling treatment, in line with experience sampling alleviating correlation neglect ($H_2$). As for our main results, the degree of diversification in response to correlation-changes increases significantly from description to numerical experience sampling ($t$-stat of 2.54). If we compare this to our results reported in Section 3, we see that the
numerical experience treatment results in a diversification effect (7.37%) that is one-third weaker than our baseline experience sampling treatment’s diversification effect (10.62%); this difference is, however, statistically insignificant.

Table A1: Experiment 1: Allocation into Diversification Asset 2 (Numerical Experience Sampling)

This table shows the average allocation to the diversification Asset 2 in % by condition (columns) and treatment (rows). t-stats are reported in parentheses. 1/2/3 asterisks denote significance at the 10%/5%/1%-level.

<table>
<thead>
<tr>
<th>Description</th>
<th>Low Correlation</th>
<th>High Correlation</th>
<th>Difference</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerical Sampling</td>
<td>31.02%</td>
<td>33.08%</td>
<td>2.06%</td>
<td>(0.88)</td>
</tr>
<tr>
<td></td>
<td>36.56%</td>
<td>29.19%</td>
<td>-7.37%**</td>
<td>(-2.54)</td>
</tr>
<tr>
<td>Difference</td>
<td>-9.43%**</td>
<td></td>
<td></td>
<td>(-2.54)</td>
</tr>
</tbody>
</table>

In summary, we find that the numerical experience sampling treatment also leads to a significant reaction in investment decisions, in line with hypothesis $H_2$. As for our main experiments, experience sampling alleviates correlation neglect, even if returns are sampled in a numerical instead of graphical format.

A.2 Continuous Return Distributions

The distribution of the returns, which we use in Experiments 1 and 2 in the paper is relatively simple, with just four return states for each asset. Therefore, we run an additional experiment, in which we use a continuous joint return distributions for the risky assets instead. This experiment provides a highly controlled robustness test in a more complex scenario. We implement this as follows: In our description treatment, we again communicate the riskiness of returns via probability statements. As distributions are now continuous, we use return ranges. Specifically, in the description treatment, participants are shown one table with potential joint return ranges of Assets 1 and 2 and the respective frequency of occurrence (Figure A2).

Although probabilities for return ranges provide only a coarse picture of the continuous normal distribution, we think this is 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. 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 experience sampling treatment, participants are presented information through the same sampling procedures as in Experiments 1 and 2. The variation in different outcomes that can be observed is of course much higher in a continuous joint distribution. Therefore, we use a stratified random sampling method to reduce the sampling error when generating the 60 different return pair draws for each participant. Stratification in this context means that we divide the distribution’s
Figure A2: Description (Continuous Return Distribution)

This figure shows how the joint normal distribution is presented in the robustness experiment for continuous return distributions in the description treatment.

<table>
<thead>
<tr>
<th>Asset 1: average annual return = 5%</th>
<th>Asset 1: average annual return = 4%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Return in %</td>
<td>Asset 2</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------</td>
</tr>
<tr>
<td>less than -5%</td>
<td>less than -5%</td>
</tr>
<tr>
<td>between -5% and 5%</td>
<td>between -5% and 5%</td>
</tr>
<tr>
<td>between 5% and 15%</td>
<td>between 5% and 15%</td>
</tr>
<tr>
<td>more than 15%</td>
<td>more than 15%</td>
</tr>
<tr>
<td>between -5% and 5%</td>
<td>less than -5%</td>
</tr>
<tr>
<td>less than -5%</td>
<td>between -5% and 5%</td>
</tr>
<tr>
<td>between 5% and 15%</td>
<td>between 5% and 15%</td>
</tr>
<tr>
<td>more than 15%</td>
<td>more than 15%</td>
</tr>
<tr>
<td>between 5% and 15%</td>
<td>less than -5%</td>
</tr>
<tr>
<td>between -5% and 5%</td>
<td>between -5% and 5%</td>
</tr>
<tr>
<td>less than -5%</td>
<td>between 5% and 15%</td>
</tr>
<tr>
<td>between 5% and 15%</td>
<td>more than 15%</td>
</tr>
<tr>
<td>more than 15%</td>
<td>less than -5%</td>
</tr>
<tr>
<td>between -5% and 5%</td>
<td>between -5% and 5%</td>
</tr>
<tr>
<td>less than -5%</td>
<td>less than -5%</td>
</tr>
<tr>
<td>between -5% and 5%</td>
<td>between -5% and 5%</td>
</tr>
<tr>
<td>less than -5%</td>
<td>less than -5%</td>
</tr>
</tbody>
</table>

support into 60 equally likely subranges before sampling. Participants are then provided with one randomly drawn return pair out of each subrange in random order. Aside from the increase in the complexity of the return distribution, general return parameters were kept 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.

Like Experiment 1, the experiment was conducted at the Frankfurt Laboratory for Experimental Economic Research with 204 participants. Participants who had taken part in Experiment 1 were excluded from the subject pool. Demographic characteristics of participants are comparable to the sample in Experiment 1 (mean age of 22.94, share of females 51%). Participants on average received a payment of 10.27 € for a one-hour session including instructions and payment. In Table A2, we report the share invested in diversification Asset 2 by presentation format treatment and correlation condition.

Despite the more complex return distribution, we are able to replicate the alleviation of correlation neglect under experience sampling. We find that participants do not significantly change their allocation in the description treatment (difference between low and high correlation of 1.62%, \( t \)-statistic of 0.55), in line with correlation neglect (hypothesis \( H_1 \)). In the experience sampling treatment, participants diversify significantly more in the low correlation condition than in the high correlation condition (difference of 8.06%, \( t \)-statistic of 3.26). The difference-in-difference between the two presentation formats is economically smaller compared to Experiments 1 and 2 and barely
Table A2: Allocation into Diversification Asset 2 (Continuous Return Distribution)

This table shows the average allocation into the diversification Asset 2 in % by condition (columns) and treatment (rows). t-stats are reported in parentheses. */**/*** denote significance at the 10%/5%/1%-level.

<table>
<thead>
<tr>
<th></th>
<th>Low Correlation</th>
<th>High Correlation</th>
<th>Difference</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>44.86%</td>
<td>43.24%</td>
<td>-1.62%</td>
<td>(-0.55)</td>
</tr>
<tr>
<td>Experience Sampling</td>
<td>45.31%</td>
<td>37.25%</td>
<td>-8.06%***</td>
<td>(-3.26)</td>
</tr>
<tr>
<td>Difference</td>
<td>-6.44%*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-1.65)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

significant at the 10% level (t-statistic of 1.65).

One potential explanation for the attenuated effect size, in addition to the increased complexity of a continuous return distribution, is the smaller variation in the frequencies of co-movements (jointly positive or jointly negative returns), even though the variation in correlations across conditions remains the same (-0.6 and +0.6). 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. Based on existing evidence that participants perceive dependence based on frequencies of return co-movement rather than correlations (Ungeheuer and Weber, 2021), the smaller effect sizes we find in Experiment 3 are not surprising.

Overall, we still find that the experience sampling treatment has a robust positive effect on participants’ responsiveness to correlation changes in their asset allocation decisions. That is, sampling alleviates correlation neglect, in line with $H_2$.

A.3 Alternative Description Format and Participants from the UK and USA

In our description treatment, we present joint probability distributions to participants by showing them a table with all potential joint return states of Assets 1 and 2 and the respective frequency of occurrence for each return pair. While this table format is concise, containing all relevant information but not more, there may be descriptive formats that allow participants to figure out that the assets are positively or negatively correlated more easily. While the considerable literature on correlation neglect has documented the insensitivity of portfolio choice to correlation under many possible description formats, we test another alternative way to communicate correlation descriptively: We provide a two-dimensional, matrix-like presentation format, similar to Table 1. Instead of presenting one row per return pair and three columns (return Asset 1, return Asset 2, frequency of occurrence, sorted by returns for Asset 1), as in Figure 3’s Panel A, we now present a table format in which the rows reflect the potential returns of Asset 1 and the columns the potential returns of Asset 2 (see Figure A3).

The experiment was run in December 2021 with 300 participants on the online platform Prolific. The final sample of participants includes 223 participants from the UK and 77 from the USA.

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4We required a Prolific score of at least 99 out of 100, excluded participants who are not fluent in English or speak English only as a second language, and required participants to be UK/US residents classified as investors by Prolific.
Participants are on average 39.41 years old, 43% are female and 70% say they hold stocks or mutual funds as a response to our own survey. The experimental procedure was the same as in Experiment 1, except for the fact that we let participants draw the full representative sample of 100 return pairs without replacement, so that the sampling error is reduced to zero. Participants were paid around £3.50 on average. This payment included a base fee of £2.50 and a bonus payment from a simulated return of their chosen portfolio (analogous to Experiment 1), where the initial investment was £1.00. Participants typically completed the experiment within approximately 20 minutes. In this experiment, we test the alternative description format against our baseline description and experience sampling treatments. As our original presentation formats from Experiment 1 are both included, this allows us to also test the robustness of our results in a different language (English) and beyond Germany (in the UK/US). Results are depicted in Table A3.

First, there is no significant difference between the alternative description format and our baseline description format. In both descriptive formats, participants do not significantly change their allocation in response to changes in correlation (difference between low and high correlation of 0.70% in the baseline, and 0.06% in the alternative description treatment). That is, results support correlation neglect in investment choice after description (hypothesis $H_1$), as for our main results.

Second, for the experience sampling treatment, we are also able to replicate the results from Experiment 1 and Experiments 2 with the new participant pool (from the UK/US, mostly investors). Participants allocate on average 6.78% less in Asset 2 in response to correlation changes ($t$-statistic: -2.89), which is in line with hypothesis $H_2$. This is a significantly stronger reaction compared to the baseline description format ($t$-statistic: 2.42), as well as the alternative description format ($t$-statistic: 2.16). Thus, the results are again consistent with experience sampling alleviating correlation neglect.
Table A3: Allocation into Diversification Asset 2 (Alternative Description Format)

This table shows the average allocation into the diversification Asset 2 in % by condition (columns) and treatment (rows). t-stats are reported in parentheses. */**/*** denote significance at the 10%/5%/1%-level.

<table>
<thead>
<tr>
<th>Description</th>
<th>Low Correlation</th>
<th>High Correlation</th>
<th>Difference</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>37.38%</td>
<td>38.08%</td>
<td>0.70%</td>
<td>(0.35)</td>
</tr>
<tr>
<td>Description Alternative</td>
<td>39.96%</td>
<td>39.84%</td>
<td>-0.12%</td>
<td>(-0.06)</td>
</tr>
<tr>
<td>Experience Sampling</td>
<td>43.08%</td>
<td>36.30%</td>
<td>-6.78%***</td>
<td>(-2.89)</td>
</tr>
<tr>
<td>Difference (Exp.Splg. - Des.)</td>
<td>-7.48%**</td>
<td></td>
<td></td>
<td>(-2.42)</td>
</tr>
<tr>
<td>Difference (Exp.Splg. - Des. Alt.)</td>
<td>-6.66%**</td>
<td></td>
<td></td>
<td>(-2.16)</td>
</tr>
<tr>
<td>Difference (Des. Alt - Des.)</td>
<td>-0.82%</td>
<td></td>
<td></td>
<td>(-0.30)</td>
</tr>
</tbody>
</table>

B Instructions: Experiment 1

All instructions and questions, translated from German into English.

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:

\[
\frac{\text{Investment}_{\text{Asset1}} \times (1 \times \text{Return}_{\text{Asset1}}) + \text{Investment}_{\text{Asset2}} \times (1 \times \text{Return}_{\text{Asset2}})}{1,000}
\]

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

Treatment\textsubscript{i} (conditional on presentation format):

Screen 3 (Introduction to Round \textit{i}):

Round \textit{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.

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:
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):

- "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):**

• 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 et al. 2014](https://ssrn.com/abstract=3086722).)

• 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 et al. 2014](https://ssrn.com/abstract=3086722).)
• 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 et al. (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 et al. (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 et al. (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 et al. (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 et al. (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 et al. (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 et al. (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 et al. (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 et al. (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 et al. (2014)].)

Note: This test is an adapted version of the financial literacy test in [Fernandes et al. (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 et al. (2012).

C Instructions: 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:

\[
\frac{\text{Investment}_{\text{Asset1}} \times (1 \times \text{Return}_{\text{Asset1}}) + \text{Investment}_{\text{Asset2}} \times (1 \times \text{Return}_{\text{Asset2}})}{1,000}
\]

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 fictitious 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").
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):

- "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").

- 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 et al. (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)