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The Influence of Different Investment Horizons on Risk Behavior

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For longer investment periods, investment consultants usually recommend a larger proportion of risky assets for investor portfolios. We examine the effect of different investment horizons on investors' risk behavior. We are interested both in participants' risk perceptions and in their asset allocation behavior. We find significant underestimations of long-term risks, which lead to a higher proportion of risky assets in the long-term portfolios. Our data show that the belief in mean reversion is a potential explanation for this behavior.

There is extensive research and debate on whether investors with longer investment horizons should hold more risky assets, such as stocks and index funds, than investors with shorter investment horizons.[1] Klos, Langer, and Weber [2003] give an overview of the large body of prescriptively oriented literature that discusses the relationship between the percentage invested in risky assets and the time horizons for the investments. On the descriptive side, Anderson and Settle [1996] and Schooley and Worden [1999] show that long-term investors do allocate a greater percentage of their funds to risky investments than short-term investors.

We follow the descriptive approach here, and investigate investor risk behavior for different investment horizons. We ask whether volatility forecasts or subjective risk assessments drive investor portfolio decisions, and whether they help explain investors' horizon-dependent behavior. As described in the next section in more detail, we investigate whether risk perception depends on time horizon. Finding a relationship between these factors, we look for possible explanations. We focus on participants' belief in mean-reverting asset prices and on their ability to transform short-term estimates into long-term estimates.

To verify the belief in mean reversion, we ask the subjects to provide long-term market expectations conditional on a short-term (upward or downward) market outcome. Recent studies (Clotfelder and Cook [1993]; Terrell [1998]) show that people are subject to the (so-called) Gambler's Fallacy, i.e., people believe that gains and losses will alternate (such as heads and tails or red and black in roulette). Recently, Odean [1998] argued that the belief in mean-reverting stock prices is a possible explanation for the disposition effect, i.e., the tendency to sell winners too early and ride losers too long (Shefrin and Statman [1985]).

An alternative explanation might be that investors have problems transferring estimates of future market values from a short-term one-year horizon to a long-term five-year horizon. If this explanation is correct, risk behavior should depend on whether subjects are presented with short-term or long-term returns.

In addition, we investigate the consistency in subjects' short- and long-term volatility forecasts. Benartzi and Thaler [1999] show that investors are influenced by the way historical returns are formatted. In their experiment, they presented the distribution of one-year or thirty-year returns for two investments, and found that in the thirty-year condition people tended to hold more risky investments in their portfolio. However, they did not ask for risk perception.

Anderson and Settle [1996] show that the presentation of long-term returns leads to a perception of higher risk and to riskier portfolio allocations. In their experiments, the participants received distributional information, communicated either as density plots, moments, or quantiles.

The remainder of this paper is organized as follows. The second section describes the design of our questionnaire. The third section presents the assessment of perceived expected returns by our participants, and the fourth section shows the results of the estimated volatilities. The fifth section studies the stated risk assessments. The sixth section examines participants' belief in mean reversion as one possible explanation of their different short-term and long-term risk behavior. In the seventh section, we study the influence of perceptional biases on portfolio decisions, and the eighth section offers our conclusions. The interaction of variables discussed so far and a preview of results can be seen in Figure 1.

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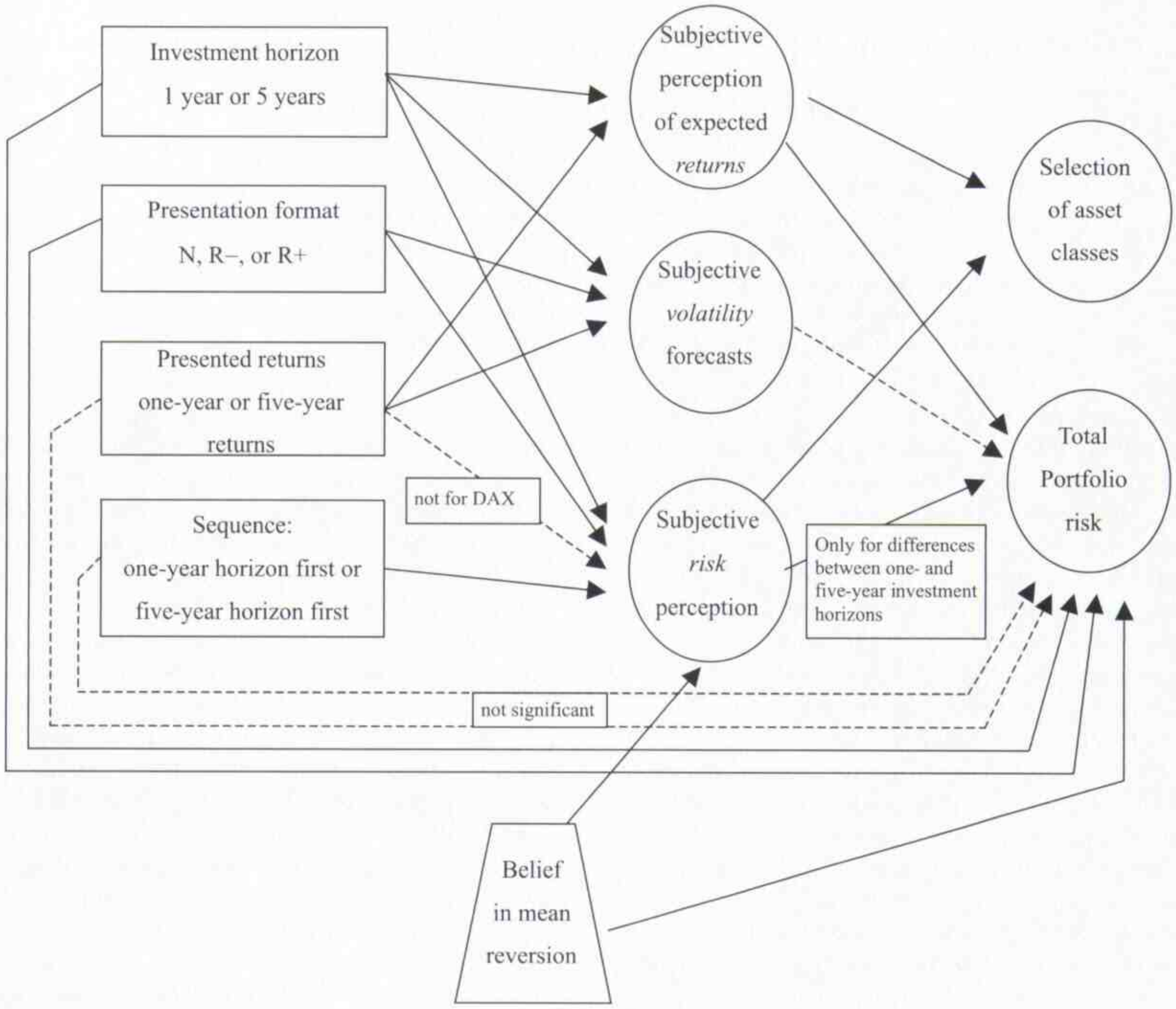
FIGURE 1
Influence of Different Conditions on Risk Perception and Investment Decisions



An Experimental Study Among MBA Students

The participants were 107 MBA students at the University of Mannheim (Germany). The questionnaire study took place in June 2000. To ensure that the participants had adequate knowledge of finance, we chose students from the advanced "Banking" course. The questionnaire had four pages. The first page contained information about the investment scenario, which the students had to follow, and information about the available investment classes. There were five informational conditions in our experiment, as detailed below:[2]

R + (1) Participants were shown the names of the three risky investment alternatives (DAX-Fund with German blue chips, SDAX-Fund with German small caps, and Dow Jones-Fund with U.S. blue chips), and historical annual returns on these investments since 1960 (see Appendix A).

R + (5) Participants were given historical five-year returns since 1960 (see Appendix B), and shown the names of the investment alternatives.

R – (1) Participants were not given the names of the alternatives, which were instead labeled "stock fund 1," "stock fund 2," and "stock fund 3." They were given historical one-year returns.

R – (5) Participants were not given the names of the risky investment alternatives, but were provided with historical five-year returns.

N Participants were given the names of the investments without any historical information.

The second page, in an envelope labeled "1," contained questions about one of the two investment horizons. Half the students were given questions with a one-year investment horizon; the other half received questions with a five-year horizon. We asked three types of questions (see Appendix C):

1. Expectations about investment returns by estimating a lower bound (10% quantile), the median value (50% quantile), and an upper bound (90% quantile) for a DM 1,000 investment in each of the risky investment alternatives.
2. Subjective risk assessments for each risky investment.
3. Portfolio allocations offering a riskless investment opportunity and the three risky investment alternatives.

After the participants filled out page 2, they were instructed to put it back into envelope "1" and open a second envelope labeled "2," in which they found pages 3 and 4. They could continue to use page 1 (the information page) while filling out pages 3 and 4, but they were not allowed to correct any statements on page 2.

Page 3 resembled page 2, with the important difference that we changed the investment horizon. So those participants who had a one-year investment horizon on page 2 now were given a five-year investment horizon, and vice versa.

Finally, on page 4 (see Appendix D), we asked the participants questions regarding their belief in mean reversion. The students were told that their investment in the DAX-Fund (or in the Stock-Fund 1 in condition R–) had won 50% or lost 25% in the first year.[3] We asked for their expectations about this investment for the following four years in the form of estimates on the lower and upper bound and the median value. We also asked two personal questions about gender and risk attitude.

Participants took about fifteen minutes to complete the questionnaire. At the end, they were offered a choice between two bars of chocolate or other types of candies worth DM 2.50. Four questionnaires were discarded because of incomplete answers, leaving 103 questionnaires.

We transformed the value estimates—the lower and upper bound ($Y^{0.1}_{ij}$ and $Y^{0.9}_{ij}$) and the median value ($Y^{0.5}_{ij}$) of participant i and asset class j (j = 1, 2, 3)—into expected returns and volatility forecasts using the Pearson and Tukey estimator (see Keefer and Bodily [1983]). We used logarithmic returns for our evaluations:[4]

$$Vol(point)_{ij} = \sqrt{\begin{pmatrix} 0.3 \cdot \ln\left(Y_{ij}^{0.1}/1000\right)^2 + 0.4 \cdot \ln \\ \left(Y_{ij}^{0.5}/1000\right)^2 + 0.3 \cdot \ln \\ \left(Y_{ij}^{0.9}/1000\right)^2 \end{pmatrix} - \left(mean_{ij}\right)^2}$$

with

$$mean_{ij} = 0.3 \cdot \ln\left(Y_{ij}^{0.1}/1000\right) + 0.4 \cdot \ln\left(Y_{ij}^{0.5}/1000\right) + 0.3 \cdot \ln\left(Y_{ij}^{0.9}/1000\right)$$

as an estimate for the mean. This estimator transforms the given quantiles by weighting them with the appropriate factors. To compare the perceived returns and volatilities with objective benchmarks, we determined the historical average log-returns $Mean(hist)_j$ and the historical volatilities (standard deviations) of the log-returns $Vol(hist)_j$ by using data since 1960.[5] The table in Appendix E shows the historical benchmarks.

Perception of the Expected Returns

Portfolio choice is driven by risk and return. Therefore, we examine the perception of expected risk and returns of our three risky asset classes. Examining returns first,[6] the following measure captures significant effects on perceptional biases (participant i and asset class j = 1, 2, 3):

$$Mean(bias)_{ij} = \frac{mean_{ij}}{Mean(hist)_j} - 1$$

One possible influence on the perception of expected returns might be individual investment horizon. Table 1 shows the mean and median biases for all asset classes for the one-year and five-year investment horizons. Five-year returns tend to be overestimated to a lesser degree than one-year returns. The one-year DAX returns tend to be overestimated on average by 0.93, but the five-year returns average only 0.50.

The results for the Dow Jones index are similar. For the small-cap SDAX index, we find an underestimation of the one-year returns,[7] but the expected return biases for the five-year investment horizon are again below the one-year biases. Using a Wilcoxon test (DAX: p = 0.001**, SDAX: p = 0.392, Dow Jones: p = 0.012*), we find significant differences between these two investment horizons in this within-subject design.

We also examine sequence effects, because we counterbalanced the sequence of the two investment horizons in the questionnaires. Using a Mann-Whitney U test, we find no significant effects for any of the three asset classes or either investment horizon.

Table 1. *Biases in Estimated Returns for Different Investment Horizons*

Bias	Mean	Median
One-year investment horizon		
DAX	.93	.82
SDAX	–.03	–.15
Dow Jones	1.59	1.09
Five-year investment horizon		
DAX	.50	.39
SDAX	–.09	–.25
Dow Jones	1.04	.69

We find significant effects with regard to the type of statistical information provided to the participants. Part of the students received historical one-year returns (conditions R–(1) and R+ (1)); the others received historical five-year returns (conditions R–(5) and R+ (5)). As Table 2 shows, participants with the long-term information tended to overestimate the expected returns compared to those with the short-term information. This holds true for all asset types and for both investment horizons.

For example, the one-year DAX returns tended to be overestimated in the one-year returns condition by an average of 0.32; in the five-year returns condition the average was 1.45. This effect is significant in a between-subject Mann-Whitney U test, except for the five-year SDAX estimates (one-year DAX: p = 0.004**, one-year SDAX: p = 0.008**, one-year Dow Jones: p = 0.000**, five-year DAX: p = 0.008**, five-year SDAX: p = 0.083, five-year Dow Jones: p = 0.006**).

Volatility Assessments

We now study the perceived standard deviations (volatilities) of the one-year and five-year log-returns.[8] We measure biases in the volatility assessments relative to our historical benchmarks (participant i and asset class j = 1, 2, 3):

$$Vol(bias)_{ij} = \frac{Vol(point)_{ij}}{Vol(hist)_j} - 1$$

We find significant influence on volatility bias for the individual investment horizon. Participants given a long-term horizon tended to underestimate the volatility to a greater degree than those with a short-term horizon. The one-year volatilities were underestimated on average between 0.05 and 0.16; the five-year volatilities were underestimated between 0.26 to 0.50, as Table 3 shows. These differences are highly significant in a within-subject Wilcoxon test (DAX: p = 0.000**, SDAX: p = 0.002**, Dow Jones: p = 0.000**). This effect is confirmed by a between-subject analysis using only the data from the first envelope.

As with the expected returns, we are interested in the informational effects of the one-year versus five-year returns in conditions R– and R+ (see Table 4). For the expected returns, we find that long-term information seems to produce higher estimates. Participants provided with the bar charts on the historical five-year returns tended to forecast higher volatility. This is not significant for all estimates in a between-subject Mann-Whitney U test (one-year DAX: p = 0.388, one-year SDAX: p = 0.945, one-year Dow Jones: p = 0.044*, five-year DAX: p = 0.013*, five-year SDAX: p = 0.103, five-year Dow Jones: p = 0.001**). The effect seems more apparent for the five-year horizon.

Subjective Risk Assessments

As an alternative measure of risk, participants were asked to rate the given asset classes on a scale from 1 to 9 according to the perceived riskiness of the asset. We analyze the differences between historical volatility and subjective risk assessment here, and explore their relevance for subsequent portfolio decisions in the seventh section.[9]

Table 2. *Biases in Estimated Returns in Different Statistical Settings*

	Statistical Information			
	One-year Returns		Five-year Returns	
Bias	**Mean**	**Median**	**Mean**	**Median**
One-year investment horizon				
DAX	.32	.19	1.45	1.02
SDAX	–.39	–.45	.21	.04
Dow Jones	.49	.73	2.63	2.47
Five-year investment horizon				
DAX	.26	.09	.76	.61
SDAX	–.19	–.37	–.02	–.18
Dow Jones	.70	.37	1.39	1.35

Table 3. *Biases in Volatility Forecasts for Different Investment Horizons*

Bias	Mean	Median
One-year investment horizon		
DAX	–.16	–.22
SDAX	–.08	–.26
Dow Jones	–.05	–.13
Five-year investment horizon		
DAX	–.40	–.47
SDAX	–.26	–.38
Dow Jones	–.50	–.59

Table 4. *Biases in Volatility Forecasts in Different Statistical Settings*

	Statistical Information			
	One-year Returns		Five-year Returns	
Bias	**Mean**	**Median**	**Mean**	**Median**
One-year investment horizon				
DAX	–.26	–.27	–.07	–.19
SDAX	–.23	–.27	–.09	–.37
Dow Jones	–.22	–.27	.17	–.03
Five-year investment horizon				
DAX	–.46	–.55	–.30	–.40
SDAX	–.36	–.49	–.22	–.28
Dow Jones	–.60	–.65	–.36	–.41

Table 5 summarizes the average subjective risk assessments for the three asset classes and the two investment horizons. The risk assessments of the five-year investment horizon tend to be below those of the one-year horizon. Comparing the short-term and long-term investment horizons with a Wilcoxon test, we again find significant within-subject differences for all asset classes (DAX: $p = 0.000^{**}$, SDAX: $p = 0.000^{**}$, Dow Jones: $p = 0.000^{**}$).

We find significant effects on subjective risk assessment from the sequence in which the horizons are presented. Participants starting with a five-year investment horizon tend to give higher risk assessments (average over all three assets is 5.46 for one year versus 5.13 for five years) than those starting with a one-year horizon (5.11 for one year versus 4.24 for five years). A Mann-Whitney U test finds significant between-subject differences in the long-term DAX and Dow Jones assessments (one-year DAX: $p = 0.997$, one-year SDAX: $p = 0.082$, one-year Dow Jones: $p = 0.103$, five-year DAX: $p = 0.001^{**}$, five-year SDAX: $p = 0.107$, five-year Dow Jones: $p = 0.011^{*}$). Consequently, we find no significant between-subject differences for only the first envelope answers, comparing one-year with five-year risk assessments.

This result is in line with psychological results that show people behave differently when evaluating decision options either separately or jointly (see Hsee et al. [1999] for a theoretical explanation). People tend to differentiate between attributes of decision alternatives that are "easy-to-evaluate" and those that are "difficult-to-evaluate." Hsee et al.'s [1999] "evaluability hypothesis" states that difficult-to-evaluate attributes have a larger impact on people's judgments and choices in a joint evaluation mode than in a separate evaluation mode. The problems our participants had with the transfer of short-term volatilities into long-term volatilities suggest that the "investment horizon" attribute is difficult to evaluate. Hence, according to the evaluability hypothesis, the investment horizon should affect risk assessments more in a joint evaluation mode.

These are exactly the results we find. When our participants answered the questions with the second investment horizon, they probably compared the two investment horizons, thus judging the investment risks in a joint evaluation mode. Consequently, the difficult-to-evaluate attribute "investment horizon" had a larger impact on their risk assessments than when they answered the questions from the first envelope, in a separate evaluation mode.

When comparing the statistical formats—the historical one- and five-year returns—we do not get the same results as for the volatility forecasts. As Table 6 shows, the five-year returns lead to higher risk assessments only for the Dow Jones index, but not for the DAX. The higher risk assessments for the Dow Jones in the five-year conditions R–(5) and R+ (5) are significant in a Mann-Whitney U test (one-year Dow Jones: $p = 0.021^{*}$, five-year Dow Jones: $p = 0.004^{**}$). The contrasting effects for the DAX are also significant (one-year DAX: $p = 0.002^{**}$, five-year DAX: $p = 0.019^{*}$). We do not find significant differences for the SDAX, however (one-year SDAX: $p = 0.566$, five-year SDAX: $p = 0.669$).

In summary, we find that the individual investment horizon significantly affects participants' perceptions of expected returns, volatilities, and risk. Their perceptions of expected returns relative to a historical benchmark are higher for the one-year scenario than for the five-year scenario. The same holds true and is significant for the forecasted volatilities.

We also find that this effect is significant for the given subjective risk assessments. However, in contrast to the estimated expected returns and volatility forecasts, sequence effects play an important role here. Appendix J presents the correlations between volatility forecasts and risk assessments for each asset class and both investment horizons. They tend to be positive but small (between 0.2 and 0.3 for the significant values).

The rational or correct relationship between these long- and short-term risk assessments depends on the appropriate risk measure and on whether people rate long- and short-term risks on the same scale. While the one-year and five-year volatility forecasts are clearly

Table 5. *Subjective Risk Assessments for Different Investment Horizons*

Risk Assessment	Mean
One-year investment horizon	
DAX	4.73
SDAX	5.41
Dow Jones	5.75
Five-year investment horizon	
DAX	4.11
SDAX	4.74
Dow Jones	5.25

Table 6. *Subjective Risk Assessments in Different Statistical Settings*

	Statistical Information	
Risk assessment	One-year Returns (Mean)	Five-year Returns (Mean)
One-year investment horizon		
DAX	5.28	4.29
SDAX	5.28	5.07
Dow Jones	5.50	6.33
Five-year investment horizon		
DAX	4.63	3.88
SDAX	4.45	4.62
Dow Jones	4.85	6.17

biased, it is not clear to what extent investors' risk assessment is irrational. Our results, however, show that comparing the long- and short-term investment situations may be one reason for the comparatively low subjective risk assessments.

Finally, we examined effects from differences in the presentation of returns. Recall that half the participants were given historical one-year returns, while the other half got historical five-year returns. For the expected returns and volatilities, we find significant evidence that presenting five-year returns leads to higher estimations. This is also true for most risk assessments, except for the DAX, for which we find a significant contrasting effect.[10]

Belief in Mean Reversion

We now investigate whether the reduced long-term risk perception might be driven by belief in mean-reverting returns. For this purpose we included an extra question about future values of a DM 1,000 investment in the DAX Fund, conditional on a given gain (of 50%) or loss (of 25%) during the first year. We obtained ninety-nine data sets for this question, as four more questionnaires were excluded from this question for incomplete information.

We denote the one-year DAX return from t = 0 to t = 1 as $R_{0\to1}$, the four-year DAX return from t = 1 to t = 5 as $R_{1\to5}$, and the five-year DAX return from t = 0 to t = 5 as $R_{0\to5}$. Because of the additivity of the log-returns, we have $R_{0\to1} + R_{1\to5} = R_{0\to5}$. With the answers on pages 2 and 3 of the questionnaire—using the Pearson and Tukey method—we can calculate the unconditional estimates for the expected value and standard deviation of $R_{0\to1}$ and $R_{0\to5}$ (see also sections 3 and 4). To determine $E(R_{0\to1})$, we use the following equation:

$$E(R_{1\to5}) = E(R_{0\to1} + R_{1\to5}) - E(R_{0\to1}) = E(R_{0\to5}) - E(R_{0\to1})$$

With the additional question, we obtain information about $R_{1\to5}$ for the case of a 50% gain ($R_{0\to1} = \ln(1.5)$) or a 25% loss ($R_{0\to1} = \ln(0.75)$). Again using Pearson and Tukey's estimation procedure, we calculate conditional expected values and conditional standard deviations of $R_{1\to5}$.

Table 7 shows the unconditional expected returns for the four years from t = 1 to t = 5 ($E(R_{1\to5})$), as well as the conditional expected returns after a gain ($E(R_{1\to5}|R_{0\to1} = \ln(1.5))$) or a loss ($E(R_{1\to5}|R_{0\to1} = \ln(0.75))$) in the first year. Our participants tended to estimate this expected return significantly higher after a loss than a gain.

The median of the expected four-year returns after a gain is 28%; after a loss it is 53%. The same holds for the means: They are 36% and 56%, respectively. Only 25% of the participants thought that the expected return would be higher after a gain than a loss. A within-subject Wilcoxon test shows that the difference between $E(R_{1\to5}|R_{0\to1} = \ln(1.5))$ and $E(R_{1\to5}|R_{0\to1} = \ln(0.75))$ is highly significant (p = 0.000**). The difference between $E(R_{1\to5})$ and $E(R_{1\to5}|R_{0\to1} = \ln(0.75))$ is also significant (p = 0.000**), but the difference between $E(R_{1\to5})$ and $E(R_{1\to5}|R_{0\to1} = \ln(1.5))$ is not (p = 0.060).

Table 7. *Unconditional and Conditional Expected DAX Returns (%)*

	Mean	Median
$E(R_{1\to5})$	39.3	35.1
$E(R_{1\to5} \mid R_{0\to1} = \ln(1.5))$	36.3	28.2
$E(R_{1\to5} \mid R_{0\to1} = \ln(0.75))$	55.6	53.0

We find evidence for the belief in mean-reverting returns by most of our participants. The effect seems to be driven especially by a strong belief in a rising DAX after a loss of 25% during the first twelve months. We return to whether this behavior could be one explanation for the underestimation of long-term risks.

To derive a more formally based measure for the belief in mean reversion, we examine participants' ideas about the correlation between the DAX return in the first year and in the following four years. This measure captures the implicit statistical interrelationship between the one-year and subsequent four-year expectations.

$$Var(R_{0\to1} + R_{1\to5}) = Var(R_{0\to1}) + Var(R_{1\to5}) + 2 \cdot \underbrace{\sqrt{Var(R_{0\to1}) \cdot Var(R_{1\to5})} \cdot \rho_{R_{0\to1}R_{1\to5}}}_{Cov(R_{0\to1}, R_{1\to5})}$$

Because we do not know $Var(R_{1\to5})$, we assume that the logarithmic returns are normal. We can therefore use the following formula to determine the implicit correlation coefficient for each participant:[11]

$$E(R_{1\to5} \mid R_{0\to1} = x) = E(R_{1\to5}) - \frac{Cov(R_{0\to1}, R_{1\to5})}{Var(R_{0\to1})} \cdot E(R_{0\to1}) + \frac{Cov(R_{0\to1}, R_{1\to5})}{Var(R_{0\to1})} \cdot x$$

For x = ln(1.5), we denote the correlation coefficient as rho1 and $Var(R_{1\to5})$ as var1. For x = ln(0.75), we denote the correlation coefficient as rho2 and $Var(R_{1\to5})$ as var2. Taking only those data sets into account, where the results for rho1 and rho2 are between –1 and 1 and the results for var1 and var2 are above zero, sixty-nine (69.7%) of our questionnaires are consistent. The following results consider only these consistent questionnaires.

Regarding the conditional expected returns, we find strong evidence that the subjects believe in mean reversion. The calculated rhos are significantly below zero (t-test: p = 0.000** and p = 0.000**). The observed distribution is illustrated in Figure 2. Rho2 (mean = –0.4) seems to be lower than rho1 (mean = –0.2). This result is in line with Table 7, which also shows that belief in mean reversion is stronger after losses than after gains. In other words, people's belief in rising stock prices after bad times seems more pronounced than their belief in falling stock prices after good times.

We now investigate whether the rhos help explain the differences between the perception of long- and short-term risks. We construct the following ratio:

$$\text{Risk ratio(DAX)} = \frac{\text{five - year risk assessment of DAX}}{\text{one-year risk assessment of DAX}}$$

We find significant correlations between the risk ratio (DAX) and rho1 (Pearson correlation = 29.4%, p = 0.014*; Spearman correlation = 35.8%, p = 0.003**), and marginally significant correlations between rho2 and this quotient (Pearson correlation = 22.1%, p = 0.068; Spearman correlation = 12.1%, p = 0.095).

We divide our participants into two groups: Those who gave a lower DAX risk assessment for the five-year investment horizon (group R1), and those who did not (group R2). We find a significantly higher rho1 (Mann-Whitney U test: p = 0.009**) for those who gave a lower long-term risk assessment than we did for those who gave the same or higher long-term assessment. This is not significant for rho2. Consequently, it is especially the participants' belief in negative returns after rising stock prices that explains the underestimation of long-term risks.

We also examine the relationship between the given conditional expected returns and the risk ratio (DAX). The following ratio is smaller the stronger the belief in mean-reverting DAX returns:

$$\text{Expected Returns Ration (DAX)} = \frac{E\left(R_{1\to 5} \mid R_{0\to 1} = \ln(1.5)\right)}{E\left(R_{1\to 5} \mid R_{0\to 1} = \ln(0.75)\right)}$$

We do not find a significant Pearson correlation (0.110, p = 0.278) between this expected returns ratio (DAX) and the risk ratio (DAX), however, we do find a marginally significant Spearman correlation of 19.5% (p = 0.054). The difference between the expected returns ratios (DAX) is marginally significant when considering consistent questionnaires (Mann-Whitney U test: p = 0.064).

To summarize, we find evidence for investors' belief in mean reversion and we believe this helps explain participants' underestimation of long-term risks. The high rate of consistent answers, as well as the significant correlation between rho1 and the risk ratio (DAX) between five-year and one-year risk assessments confirms this proposition. The explanatory power of the belief in mean reversion seems to be larger for those who gave consistent conditional expectations for future DAX values.

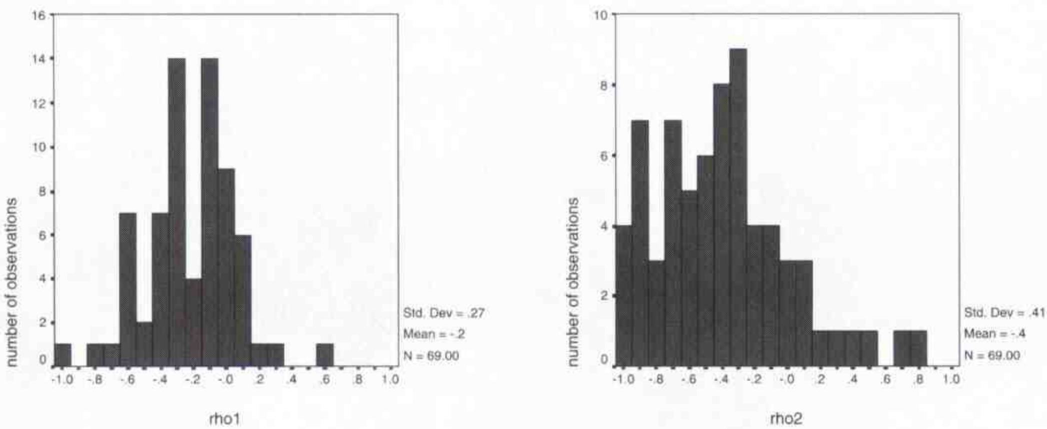
Investment Decisions

Finally, we are interested in portfolio choices and possible explanations for these choices (see Appendix I). We compute portfolio risk for both investment horizons using the returns, volatilities, and correlations estimated with our historical data since 1975 (see Appendix E).

$$Portfolio - Risk = \sqrt{\sum_{i=1}^{3}\sum_{j=1}^{3} x_i \cdot x_j \cdot \sigma_i \cdot \sigma_j \cdot \rho_{ij}}$$

x_i denotes the proportion of the three asset types (DAX: i = 1, SDAX: i = 2, and Dow Jones: i = 3), σ_i is the historical standard deviation, and ρ_{ij} is the histori-

FIGURE 2
Histograms of rho1 and rho2



cal correlation between assets i and j ($\rho_{ij} = 1$ for i = j). As one would expect, we find high correlations between total portfolio risks and the stated risk attitude for the one-year horizon (correlation = 0.418, p = 0.000**) and the five-year horizon (correlation = 0.360, p = 0.000**).

We find significant differences between the one-year and five-year portfolio risk. The mean one-year portfolio risk is 13.91%, while the average five-year portfolio risk is 14.85%. This difference is significant in a Wilcoxon test (p = 0.011*), and is confirmed by Figure 3, which shows the mean portfolio proportions for the two investment horizons. When the participants operated in the short-term investment horizon, they invested 28.4% in the riskless asset. In the long-term investment horizon, however, they tended to reduce this proportion by about 5%.

A within-subject comparison also confirms the following tendency: Fifty-one participants increased the portfolio risk for the long-run portfolio compared to their short-term portfolio, but only thirty-three accepted less portfolio risk for the five-year horizon compared to the one-year. Nine participants did not change the entire portfolio risk when deciding for the second investment horizon.

Although we cannot identify a significant sequence effect on portfolio risk—probably because of the high variability in our data—it does seem to have some influence on portfolio choice. Participants who began with the five-year investment horizon show no tendency to accept more portfolio risk over the long run. Twenty-two accepted more risk for the five-year horizon, and twenty-one accepted less risk. In the other condition, however, twenty-nine of the fifty participants increased the risk of the long-term portfolio after being confronted with the short-term portfolio. Only twelve decreased portfolio risk over the long run.

Analogously, we find a much larger difference, 1.58%, between long-term and short-term portfolio risk when participants began with the one-year investment horizon, compared to the small difference of 0.32% when participants began with the five-year horizon. The influence of the sequence condition on the difference between long-term and short-term portfolio risk is marginally significant in a Mann-Whitney U test (p = 0.088).

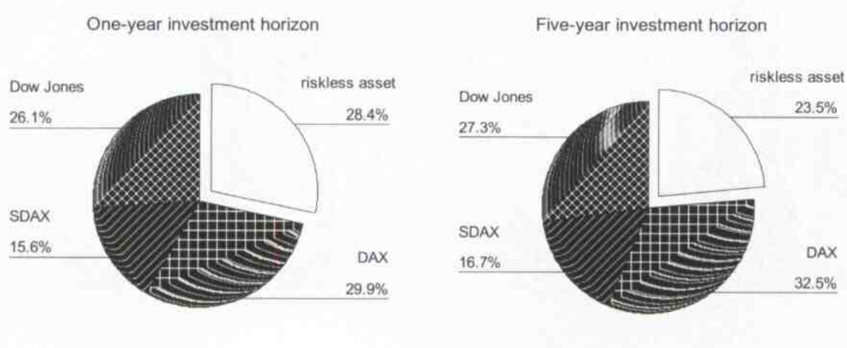
This result is in line with our sequence-dependent risk assessment results presented earlier. Recall that the reduction of risk assessments in the one-year/five-year condition is larger than the rise of risk assessments in the five-year/one-year condition. This implies that the attribute "long-run investment horizon" is especially "difficult-to-evaluate." According to the evaluability hypothesis of Hsee et al. [1999], the evaluation of the five-year investment horizon in a joint mode, i.e., in the second envelope, would drive differences between the two investment horizons. This is confirmed by the portfolio choice.

As the results of Benartzi and Thaler [1999] suggest, participants receiving the historical five-year returns tend to accept higher portfolio risk. But we do not find that these effects are significant, possibly because the presentation of five-year instead of one-year returns has two effects. On the one hand, expected returns are perceived more intensively. But on the other hand, both volatility and risk tend to be overestimated. Thus, these two effects may cancel each other out.

To learn about the effect of different investment horizons on portfolio choice, we further examine which factors drive the observed *difference* between the one-year and five-year portfolio risk (see Table 8). Using the difference between the two portfolio risks and the difference between the sums of all one- and five-year risk assessments, we find a significant Pearson correlation of –0.199 (p = 0.044*) and a significant Spearman correlation of –0.252 (p = 0.010**).

However, we only find a significant correlation between portfolio risk differences and the difference of the sums of all one- and five-year volatility estimation biases if we determine the Spearman correlation coefficient (correlation = –0.230, p = 0.019*). The difference between the sum of all expected return biases for the five-year and one-year investment horizons explains differences in portfolio risk very well (Pearson

FIGURE 3
Mean Portfolio Proportions



correlation = 0.401, p = 0.000**; Spearman correlation = 0.222, p = 0.024*).

Thus, we also find that volatility forecast biases significantly influence willingness to accept portfolio risk, while the risk assessments seem to have more explanatory power.

Finally, we explain the risk-friendly behavior over the long run. Belief in mean reversion is measured by the implicit correlation coefficient and by the ratio of the two conditional expected DAX returns. This belief apparently drives the different short- and long-term investment behavior.

We find negative correlations between the estimated rho1 and rho2 and the difference between the five-year and one-year portfolio risk. Table 9 shows this correlation is significant for rho1 (Pearson correlation = –0.381, p = 0.000**) but not for rho2 (Pearson correlation = –0.085, p = 0.488). The calculated Spearman correlations confirm this result. This means that the smaller rho1 (or rho2), the greater the belief in mean reversion, and the bigger the difference between long- and short-term portfolio risk. To confirm this result, we use the expected returns ratio (DAX) as an alternative measure for participants' belief in mean reversion. Table 9 shows no significant Pearson correlations, but the Spearman correlations are significant for both the consistent participants and for all participants.

To test the impact of these two measures on our participants' belief in mean reversion, we use another method. We divide the participants into two nearly equal groups. The participants who increased their long-term portfolio risk compared to their short-term portfolio risk are denoted "group P1"; all others are denoted "group P2."

Table 9 shows the mean values for rho1, rho2, and the expected value quotient (DAX) for both groups. All measures tend to be smaller for group P1. We use a Mann-Whitney U test to examine whether the difference between the two groups is significant. Our results show that rho1 of group P1 is significantly smaller than rho1 of group P2 (p = 0.003**), which confirms that investors who increased their portfolio risk in the long run (group P1) show a stronger belief in mean reversion. This is again not significant for rho2 (p = 0.118).

For the expected returns ratio (DAX), we find a significant difference between the two groups only among the consistent participants (p = 0.038*). However, for all participants the effect is still marginally significant (p = 0.084).

Conclusion

We examine the effect of different investment horizons on risk perception, expected returns, and portfolio choice. We find significant differences between short-term and long-term risk perception. Both the estimated volatilities and the subjective risk assessments depend on the given investment horizon. We find that biases in risk assessments, rather than biases in estimated volatilities, drive the observed investment behavior. Consequently, we also detect significant differences in the short- and long-term total portfolio risk that participants are willing to take.

Table 8. *Correlation Between Differences Of Portfolio Risk and Total Perceptions*

	Correlation of the difference between one- and five-year portfolio risk and …		
	…the difference between one- and five-year biases in perceived expected returns.	**…the difference between one- and five-year biases in volatility forecasts.**	**… the difference between one- and five-year total subjective risk assessments.**
Pearson correlation	+0.401 (p = 0.000**)	–0.121 (p = 0.223)	–0.199 (p = 0.044*)
Spearman correlation	+0.222 (p = 0.024*)	–0.230 (p = 0.019*)	–0.252 (p = 0.010**)

Table 9. *Correlation Between Differences Of Portfolio Risk and Belief in Mean Reversion*

	Rho1 (N = 69)	**Rho2 (N = 69)**	**Expected Returns Ratio (DAX)**	
			N = 69	**N = 99**
Pearson correlation with difference between long- and short-term portfolio risk	–0.381 (p = 0.001**)	–0.085 (p = 0.488)	–0.009 (p = 0.947)	–0.098 (p = 0.334)
Spearman correlation with difference between long- and short-term portfolio risk	–0.359 (p = 0.002**)	–0.156 (p = 0.201)	–0.240 (p = 0.047*)	–0.211 (p = 0.036*)
Mean for group P1	–0.31	–0.48	0.30	0.19
Mean for group P2	–0.12	–0.30	0.84	0.79
Significance of difference between P1 and P2 (Mann-Whitney U test)	p = 0.003**	p = 0.118	p = 0.038*	p = 0.084

One reason for this behavior seems to be the belief in mean-reverting asset prices. Most of our participants believe in this mean reversion, even though empirical results suggest that the subsequent four-year return is positively correlated with the first-year return (see Bromann, Schiereck, and Weber [1997], Schiereck, DeBondt, and Weber [1999], and DeBondt and Thaler [1989] for a survey). The belief in mean reversion seems to drive the long-run risk-taking behavior. Furthermore, we cannot reject limited cognitive abilities as another reason for this specific horizon-dependent risk behavior.

Notes

1. See also Kritzman [1994].
2. Our analysis here does not differentiate between presentation conditions R+, R , and N. A related paper by Siebenmorgen, Weber, and Weber [2001] investigates the effect of presentation, i.e., the effect of different conditions on risk perception and portfolio choice. Siebenmorgen, Weber, and Weber [2001] use a different data set based on more presentation conditions and a larger set of investment alternatives.
3. We used these returns because they are approximately the 5% and 95% quantiles of the estimated distribution of the one-year DAX returns.
4. The logarithmic functions are due to the kind of returns we use here. We get similar results with standard returns, but we use logarithmic results because we need the additivity later.
5. For the small caps we could not obtain data since 1960, so we estimated the historical benchmarks with data since 1975.
6. Appendix F shows the mean and median values for the five different information conditions and the two sequence conditions.
7. This is probably due to the different time periods underlying the historical benchmark. However, this does not matter, as we are only interested in the differences between the one- and five-year investment horizon.
8. Appendix G shows the average and median volatility forecasts for the five information conditions and the two sequence conditions.
9. The average results for all information conditions and the two sequence conditions are illustrated in Appendix H.
10. Because the historical volatility of the Dow Jones five-year returns is much higher than that of the DAX five-year returns, this result is quite understandable, even though the one-year volatilities are nearly the same. Most of the participants in the five-year return conditions R (5) and R+ (5) realized that the Dow Jones was a riskier investment than the DAX. Consequently, they tended to give different risk assessments for the three asset classes, which led (in the five-year return condition) to the Dow Jones risk assessments being higher and the DAX risk assessments being lower.
11. See Green [1993, p. 73, formula 3-80].

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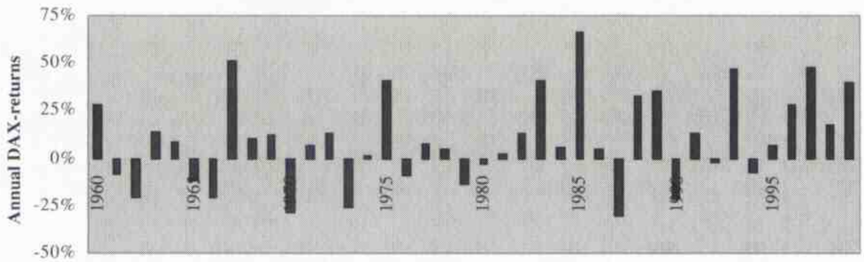
APPENDIX A
Questionnaire (Page 1, Annual Returns)

Investment Questionnaire

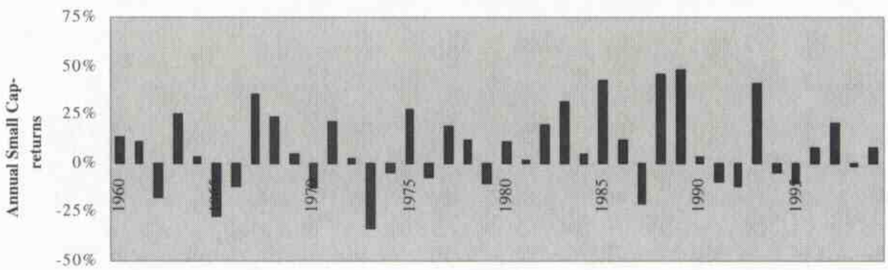
Please imagine, you will inherit **DM 500,000** in the next days. But you must not consume this money; you have to decide today, how to invest it.

The following investment alternatives are available:

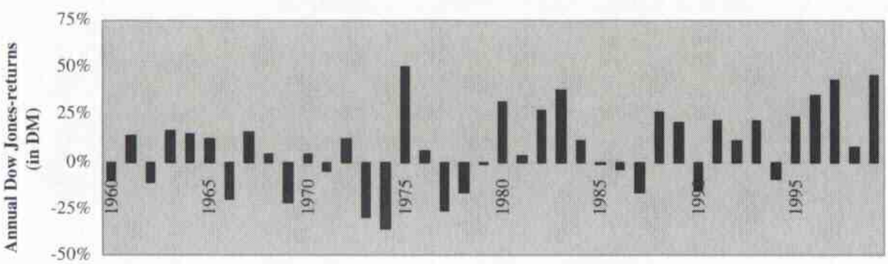
- „riskless investment" investment without price risk and with sure payments with a annual rate of return of 5%
- „DAX-Fund" portfolio of 30 German Blue Chips, as they are in the German Stock Index DAX



- „SDAX-Fund" portfolio of smaller German stocks, whose market capitalization is ranked 101 to 200, as they are in the German Small Cap Index SDAX



- „Dow Jones-Fund" portfolio of 30 U.S. Bluechips, as they are in the index Dow Jones



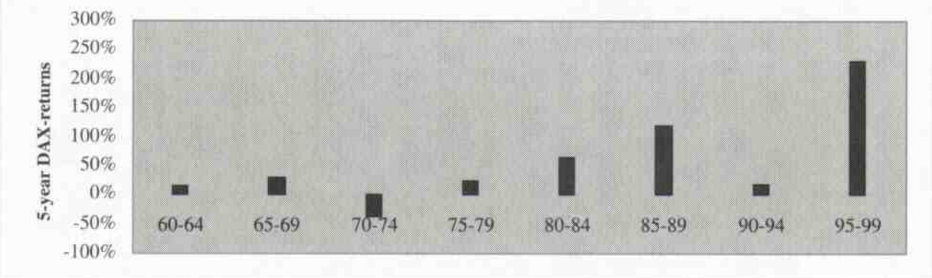
APPENDIX B
Questionnaire (Page 1, Five-year Returns)

Investment Questionnaire

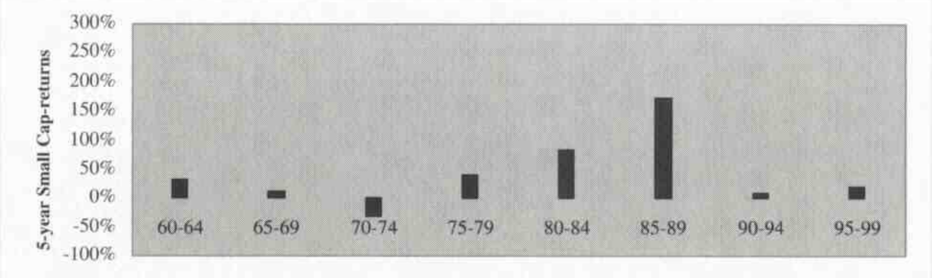
Please imagine, you will inherit **DM 500,000** in the next days. But you must not consume this money; you have to decide today, how to invest it.

The following investment alternatives are available:

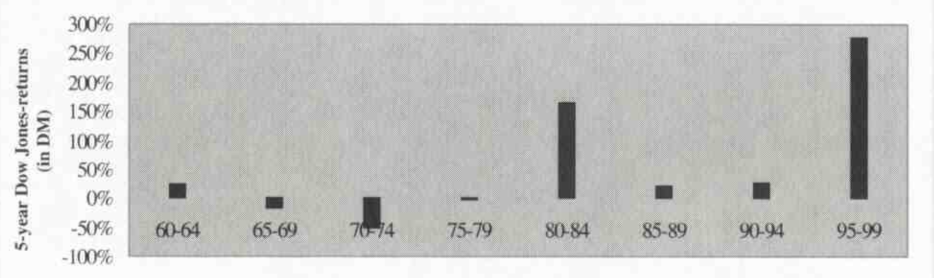
- „riskless investment" investment without price risk and with sure payments with a annual rate of return of 5%
- „DAX-Fund" portfolio of 30 German Blue Chips, as they are in the German Stock Index DAX



- „SDAX-Fund" portfolio of smaller German stocks, whose market capitalization is ranked 101 to 200, as they are in the German Small Cap Index SDAX



- „Dow Jones-Fund" portfolio of 30 U.S. Bluechips, as they are in the index Dow Jones



APPENDIX C
Questionnaire (Pages 2/3)

Please imagine, you would like to invest your money for 12 months. **So your investment horizon is 1 year.**

How do you assess future values of the mentioned investment alternatives in the next 12 months? Please consider all gains/losses, dividend payments and if necessary exchange rate risks.

If you invest today DM 1,000 into the mentioned investments, what are these DM 1,000 worth in **one year**? Please state the amount of money (in DM), of which you think the real value in 12 months will, ...

lower bound: ... rather not (i.e. in only **10%** of all cases) remain under it.
median: ... equally likely exeed it or remain under it.
upper bound: ... rather not (i.e. in only **10%** of all cases) exeed it.

1000 DM will be...	**in DAX-Fund**	**in SDAX-Fund**	**in Dow Jones-Fund**
lower bound	DM	DM	DM
median	DM	DM	DM
upper bound	DM	DM	DM

How do you assess the risk of these three investments on a **scale from 1 to 9** ? (1= no risk; 5=moderate risk; 9=highest risk)

	DAX-Fund	**SDAX-Fund**	**Dow Jones-Fund**
risk assessment			

How do you allocate your new wealth of DM 500,000 for the next 12 months using the available investment alternatives, if you are not allowed to change your portfolio allocation during the next 12 months?
Please insert percentages.

Riskless investment with a return of 5%	%
DAX-Fund	%
SDAX-Fund	%
Dow Jones-Fund	%
Sum	**100%**

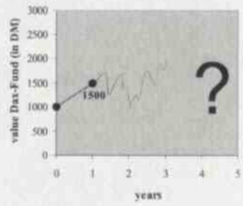
Please make sure, that your portfolio portions add up to 100%.

APPENDIX D
Questionnaire (Page 4)

Extra question:

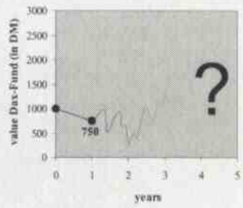
Please imagine, after one year an investment of DM 1,000 into the DAX-Fund has reached an value of **DM 1,500**. So the DAX-Fund has won 50% after 12 months. What do you think in such a situation, what is this investment worth after 4 more years (5 years altogether)? Please estimate again the lower bound, the median and the upper bound of the final value.

After 5 years DM 1,000 invested in the DAX-Fund will be worth, ...	... if DAX-Fund has won 50% after the first year.
lower bound	DM
median	DM
upper bound	DM



And what about a DM 1,000 investment into the DAX-Fund after 5 years, if it is worth only **DM 750** after the 12 months?

After 5 years DM 1,000 invested in the DAX-Fund will be worth, ...	... if DAX-Fund has lost 25% after the first year.
lower bound	DM
median	DM
upper bound	DM



Finally two personal questions:

Are you ☐ male or ☐ female ?

How would you assess your risk attitude in such a situation, in which you have to invest DM 500,000 DM? Please mark the scale.

conservative — moderate — aggressive

Thank your very much for your help.

Appendix E. *Historical Data*

	Data since 1960 (%)		Data since 1975 (%)	
	One-year log-returns	Five-year log-returns	One-year log-returns	Five-year log-returns
DAX				
Mean	7.0	35.2	11.4	57.0
Standard deviation	21.9	48.5	21.4	42.8
SDAX				
Mean	—	—	8.5	45.2
Standard deviation	—	—	17.3	36.6
Dow Jones				
Mean	5.2	25.8	10.8	54.2
Standard deviation	20.6	63.3	19.5	57.6

Note: We calculated the DAX and Dow Jones data from reports of the Deutsche Bundesbank; the SDAX[1] data was received from the Deutsche Börse AG.

[1]SDAX data were not available before 1988, so small-cap returns from 1975-1987 come from Beiker [1993]. For the presentation in the questionnaires we estimated a bivariate normal distribution of DAX and SDAX and simulated the SDAX returns from 1960 to 1974.

Appendix F. *Estimation of Expected Returns*

	Information Conditions									
	N		R–(1)		R–(5)		R+(1)		R+(5)	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
One-year investment horizon										
Page 2										
DAX	.15	.15	.07	.06	.24	.14	.06	.06	.14	.15
SDAX	.11	.11	.06	.05	.12	.05	.04	.03	.10	.11
Dow Jones	.18	.14	.06	.05	.23	.16	.06	.06	.13	.19
Page 3										
DAX	.14	.14	.14	.15	.14	.13	.10	.09	.18	.17
SDAX	.09	.10	.07	.05	.13	.09	.05	.05	.08	.07
Dow Jones	.10	.09	.11	.11	.19	.15	.07	.09	.21	.21
Five-year investment horizon										
Page 3										
DAX	.47	.42	.50	.23	.67	.54	.51	.46	.64	.61
SDAX	.38	.34	.44	.25	.44	.28	.44	.38	.53	.56
Dow Jones	.52	.34	.51	.20	.62	.64	.53	.47	.62	.61
Page 2										
DAX	.55	.51	.51	.53	.74	.61	.28	.26	.48	.53
SDAX	.50	.36	.37	.24	.57	.40	.23	.22	.27	.26
Dow Jones	.52	.51	.47	.36	.71	.66	.27	.26	.54	.52

Appendix G. *Volatility Forecasts*

	Information Conditions									
	N		R–(1)		R–(5)		R+(1)		R+(5)	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
One-year investment horizon										
Page 2										
DAX	.15	.18	.20	.21	.26	.20	.15	.15	.22	.19
SDAX	.21	.19	.14	.14	.19	.14	.12	.12	.19	.18
Dow Jones	.14	.14	.21	.22	.33	.25	.14	.15	.21	.18
Page 3										
DAX	.21	.25	.19	.18	.18	.18	.13	.07	.17	.10
SDAX	.22	.16	.17	.16	.10	.10	.11	.05	.14	.07
Dow Jones	.20	.19	.16	.17	.21	.20	.15	.12	.23	.14
Five-year investment horizon										
Page 3										
DAX	.24	.23	.25	.22	.49	.43	.22	.22	.32	.28
SDAX	.30	.32	.22	.19	.35	.18	.19	.21	.35	.33
Dow Jones	.25	.26	.26	.21	.57	.56	.20	.22	.37	.38
Page 2										
DAX	.24	.21	.45	.35	.33	.36	.15	.14	.26	.27
SDAX	.31	.22	.41	.25	.26	.27	.14	.13	.19	.13
Dow Jones	.26	.23	.40	.29	.41	.47	.17	.13	.32	.26

Appendix H. *Subjective Risk Assessments*

	Information Conditions (Mean)				
	N	R–(1)	R–(5)	R+(1)	R+(5)
One-year investment horizon					
Page 2					
DAX	3.90	5.71	4.33	5.50	4.50
SDAX	6.40	4.57	4.44	4.75	5.25
Dow Jones	4.00	5.43	6.89	5.42	5.67
Page 3					
DAX	5.18	5.50	3.89	4.55	4.33
SDAX	6.27	6.50	4.67	5.18	5.67
Dow Jones	6.00	4.90	6.67	6.18	6.33
Five-year investment horizon					
Page 2					
DAX	2.70	4.71	3.78	3.42	3.75
SDAX	5.30	4.29	4.22	3.67	4.67
Dow Jones	3.10	5.29	6.44	3.58	5.50
Page 3					
DAX	4.36	5.80	3.89	4.82	4.08
SDAX	5.73	5.50	4.11	4.45	5.25
Dow Jones	5.18	5.20	7.22	5.64	5.83

Appendix I. *Portfolio Proportions*

	Information Conditions									
	N		R–(1)		R–(5)		R+(1)		R+(5)	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
One-year investment horizon										
Page 2										
Riskless	.24	.23	.36	.40	.30	.25	.25	.23	.35	.23
DAX	.31	.30	.16	.20	.32	.33	.30	.28	.26	.30
SDAX	.14	.15	.21	.20	.18	.20	.15	.10	.15	.20
Dow Jones	.31	.25	.27	.25	.21	.20	.30	.28	.23	.28
Page 3										
Riskless	.24	.20	.35	.28	.28	.25	.27	.30	.23	.20
DAX	.34	.30	.28	.25	.31	.30	.37	.40	.30	.30
SDAX	.18	.15	.09	.05	.21	.20	.16	.11	.12	.10
Dow Jones	.24	.30	.29	.28	.19	.15	.20	.15	.35	.30
Five-year investment horizon										
Page 3										
Riskless	.23	.20	.26	.20	.32	.20	.20	.10	.14	.14
DAX	.31	.35	.25	.25	.30	.33	.33	.35	.42	.38
SDAX	.17	.15	.19	.20	.19	.17	.15	.13	.18	.20
Dow Jones	.29	.30	.31	.30	.20	.20	.32	.40	.26	.30
Page 2										
Riskless	.24	.25	.35	.30	.27	.25	.21	.20	.20	.13
DAX	.32	.30	.22	.23	.38	.35	.36	.30	.32	.30
SDAX	.20	.20	.12	.13	.19	.15	.18	.20	.13	.13
Dow Jones	.24	.25	.32	.30	.15	.10	.26	.25	.35	.30

Appendix J. *Correlations Between Volatility Forecasts and Risk Assessments*

Investment	Horizon	Correlation (Pearson)	Correlation (Spearman)
DAX	One-year	0.218 (p = 0.027*)	0.205 (p = 0.038*)
SDAX	One-year	0.284 (p = 0.004**)	0.304 (p = 0.002**)
Dow Jones	One-year	0.173 (p = 0.081)	0.065 (p = 0.516)
DAX	Five-year	0.107 (p = 0.281)	0.081 (p = 0.416)
SDAX	Five-year	0.140 (p = 0.159)	0.090 (p = 0.364)
Dow Jones	Five-year	0.222 (p = 0.024*)	0.216 (p = 0.029*)