Which Risk Attitude Components are related to Intelligence?

A critical review of the literature

Oosthoek, Wouter .W. 360407 , Erasmus University Rotterdam

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Abstract: In this thesis risk attitudes and inter-temporal choices are related to intelligence. By comparing and reviewing existing research on the subject the form and nature of this relation will be determined. Several subjective attitude components are considered: Likelihood insensitivity, risk aversion, and time preferences. Based on the combined knowledge of existing papers it is concluded that higher intelligence leads to more risk neutral and more patient behavior. For the component likelihood insensitivity indications of a relation are found, however to truly determine the nature of this relation more information and research is required.

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1. Introduction

How risk attitude relates to rationality is a topic that has been discussed frequently in behavioral economics. People tend to not be fully rational and sometimes take unnecessary risks. The behavior of investors for example tends to be influenced by cognitive biases (Subrahmanyam, 2008). Much research has been conducted regarding the rationality and risk behavior of people. However, how this risk behavior relates to intelligence is a topic that has not seen a lot of research. People with different levels of intelligence may see risks differently and thus take different actions, (Peters, Västfjäll, Slovic, Mertz, Mazzocco, & Dickert, 2006) Numeracy, a factor influenced by cognitive skills could influence to processing of information, and thus possibly the decision making. (Keller, Kreuzmair, Leins-Hess, & Siegrist, 2014). For children the rationality of their behavior is seen as a great influence on the rest of their lives (Petrie & Castillo, 2014). This thesis will study whether intelligence is the cause of this difference in rational behavior. This study will thus try to uncover the relationship between intelligence and the risk attitude and hence the research question is:

Which risk attitude components are related to intelligence?

The incentive of conducting this research comes from the limited availability of data regarding risk attitude related to intelligence. By conducting this research I hope to create a collection of information available about this subject. Literature regarding the subject will be assessed and related to the research question. With the combined information perhaps a pattern and possibly a correlation between intelligence and risk attitude can be found.

To answer the research questions literature will be studied which includes some sort of measure of cognitive functions. These measures will be related to the risk taking behavior to see whether intelligence has an influence on risk attitude .

To fully understand the relation risk attitude is not investigated as one unit but instead it is split into several parts. For each of these parts the existing research will be assessed. These components make it easier to assess whether or not a relation exists for the whole of risk attitude or merely for some components or situations.

This paper is organized in the following way. The risk attitude components that will be studied and related to intelligence will first be explained in a theoretical framework. In order to compare the different papers the measurement of both intelligence and risk attitude are compared. After making these comparisons the different risk attitude components will be related to intelligence. The results

for the different components will be discussed in the final part of the paper. This paper will end with a conclusion and an answer to the research question.

2. Theoretical Framework

2a. Defining Intelligence

The purpose of this research is thus to relate risk attitude and intelligence. To relate the two variables they first need to be defined in ways such that they can be measured and such that the nature of the relation can be uncovered. This theoretical framework will try to define the terms that are used in this research. The first term concerns *intelligence*. The research conducted is a literature review, which gives insights into many papers and articles. Each paper has its own different interpretation of intelligence, but there are many similarities. Intelligence is often measured by some test which looks at cognitive abilities or skills. The common pattern in these papers is that intelligence is defined through cognitive abilities. These cognitive abilities can be measured by different tests; the most common example is an IQ test. By defining intelligence as cognitive ability it becomes possible to find measurement in this variable, however the way cognitive abilities are uncovered differs in each article and paper. In order to successfully study a possible relation between risk attitude and intelligence the way cognitive abilities are measured will be studied. Intelligence is difficult to measure with one single variable. Brody (1999) tries to explain what a single measurement, particularly IQ measurement, means for the uncovering of intelligence. Intelligence is not a fixed number throughout the life of individuals. It is argued that intelligence is susceptible to change. IQ is seen as a good measurement of intelligence or cognitive skills. Measure (2008) argues that while intelligence might not be fully explainable yet, the IQ test provides the best alternative to measure the intelligence and cognitive skills.

2b. Defining Risk attitude

The other aspect which needs to be defined is risk attitude. To properly explain risk attitude I will start off at the basic level and provide the terminology to fully explain the risk attitude components. Not all aspects of risk attitude will be explained or discussed as they are not all relevant. The focus on this thesis will not be on the technical parts of papers and articles, but rather on the implications of the results of these papers. Most concepts of risk attitude will only be discussed briefly. Risk attitude explains the way people behave when taking decisions under risk. This means that a certain decision maker is confronted with different choices and for each choice there is a probability and a payoff. These choices are named *prospects* (Wakker, 2010). Each prospect has its expected value. The

decision maker wants to maximize his own utility and therefore will choose in a way that does so. In the general model of decision making people choose the highest expected utility when their behavior is fully rational. This means that when people are rational they will choose the highest expected value when confronted with a decision under risk. Behavior under risk is however most likely not fully rational. With the risks taken into account it will be examined how rational certain aspects are of the risk attitude. The *rationality* described in this thesis means that the decisions are taken in the most logical and mathematical best way. A rational decision does not mean that the highest payoff is always realized, for the decisions are taken under risk. This means that even when the most rational option is taken, the outcome could still vary.

A concept which needs to be understood in order to understand risk preferences is the certainty equivalent. The *certainty equivalent* is the point where for a certain gamble the decision maker is indifferent between taking the gamble or taking a certain payoff (Wakker, 2010). By analyzing the certainty equivalent the preferences of the decision maker can be found. For example when the certainty equivalent is lower than the expected value of a gamble this indicates that the decision maker prefers a low certain payoff compared to a higher payoff under risk, this thus means that the decision maker is risk averse. It works the same the opposite way, if the certainty equivalent is higher than the expected value of the gamble the decision maker is risk seeking. The certainty equivalent is often investigated in order to understand risk attitude, and it is thus vital to understand how certainty equivalents are constructed.

A special focus will be on *likelihood insensitivity*, as this is a relative new concept in behavioral economics. To understand this first likelihood insensitivity, or Inverse-S needs to be explained. Likelihood insensitivity relates to probability weighting, particularly the diminishing sensitivity towards probabilities. People tend to overweight small probabilities and underweight high probabilities, (Wakker, 2010) the inverse S curve depicts the weighting of these probabilities. The name inverse S comes from the shape of the function which depicts probability weighting. When plotting the probabilities of 0 to 1 against the weighting of the probabilities, a fully rational person would give a perfectly linear line along a 45 degree angle. The inverse S shape is created through the underweighting of high probabilities, which makes the graph go under the 45 degree line in the upper regions of the function. The overweighting of low probabilities leads to the graph going above the 45 degree line (Wakker, 2010).

Another concept which is also studied in several papers alongside risk attitude is the patience of decision makers. By assessing the choices the subjects make in inter-temporal situations the (im)patience of subjects is assessed. (Im)Patience in this instance refers to whether decision makers

prefer a lower payoff now or a higher payoff later. This is also a variable with possible connections to intelligence and in a similar vein as risk attitude. This is why papers investigate both the risk attitude and the inter-temporal choices of subjects. While inter-temporal choice is not a direct component of risk attitude, the influence of cognitive ability on this variable may have implications for risk attitude. For this reason inter-temporal decision making is taken into account in this thesis.

3. Comparing measurements of intelligence

Different ways of measurement could lead to different conclusions. Can some conclusions be trusted and others not? This is why it is vital to study the ways intelligence is measured. The most often encountered way are simple tests which measure cognitive ability. A good example is Frederick (2005). In Frederick (2005) a cognitive test was performed which has 3 problems. Each problem is designed in a way that the most intuitive answer is wrong. When enough thought is put into the question, thus it is not filled in impulsively, then the right answer can easily be discovered. For example the first question is as follows: A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost? The first thing that springs to mind is that the ball costs $0.10 .

However this answer is obviously wrong when enough thought is put into the question. Frederick (2005) had different ways to support the fact that the intuitive question was the wrong one. When assessing the difficulty of the question, those who had answered wrong thought the problem was easier compared to those who answered the answer correctly. This is one of many controls that were performed. Through these controls we could be certain to an extent that the questions were counter-intuitive. Through the design of the questions the patience and cognitive ability of the subjects can be measured and compared.

Frederick (2005) had a sample of 3428 subjects. A pool of subjects of this size creates much credibility to the conclusions of this paper. The results of the three questions are compared to questionnaires which measured risk preferences. This way the link with risk attitude is created and conclusions can be made. The way Frederick (2005) create a measurement of cognitive ability is simple yet rewarding. The results of questions asked create groups of different cognitive ability.

A similar cognitive ability test is created in Gayer (2010) where the mental process of subjects is investigated. The subjects face simple lotteries and have to make a decision on which lottery they prefer. The subjects face different lotteries several times, in this way the consistency of the subject is tested. The effect of the consistency on the perceived probabilities is then taken as the cognitive measure. Another example of where the performance of tests is taken as an indicator of intelligence

is Einhorn & Hogarth (1985). Here the way the subjects perform in test based on attitude towards ambiguity is taken as an indicator of intelligence. This is an example of a weaker indicator of intelligence compared to the previous tests which purely focused on cognitive skills. In this example higher results do not necessarily lead to higher intelligence.

Often the test conducted to measure intelligence are already existing tests. In Burks, Carpenter & Rustichini (2009) the cognitive abilities are measured in three different ways. The participants were subjected to an IQ test, a numeracy test, and a game versus a computer called Hit 15 which measured the subjects' ability to plan ahead. In this instance an already existing IQ test was included in the measurement. Another instance where an IQ test is included is Dohmen, Falk, Huffman & Sunde (2010). Here the IQ test used is one verbal and one non-verbal. The subjects are interviewed in their own homes. This could lead to different results than when taken in a different environment. In Eckel, Grossman, Johnson, de Oliveria, Rojas & Wilson (2012) no IQ test is taken as indicator but instead they use a Literacy test and a life skills survey. In Taylor (2013) a numeracy test and a cognitive ability test designed by Weller (2013) is used. These tests measure similar variables as the IQ tests and thus create similar results on intelligence. While the use of existing IQ tests or similar tests seem the most straight forward way to gain an quick measurement of the subjects' intelligence, it is also often seen that researchers opt for other ways of measurement.

Benjamin, Sabsian, & Shapiro (2013) uses another different method. The results of students in school is taken as a measure of their intelligence. It is argued with the use of existing research that the school grades of students and the results on standardized exams are positively related to the cognitive ability of the students. This method is close to the use of an IQ test, for the results of the school grades give an indication of the cognitive ability. Arguments can be found both in favor of this method and against it. The IQ test gives a measurement at one particular moment, whereas the school grades are the average of many measurements during the course of years. However school grades are not a direct measurement of cognitive ability, IQ test on the other hand do measure the cognitive abilities. While both have pros and cons, both can be seen as solid measurements of intelligence.

In Gonzalez, Dana, Koshino & Just (2005) an unusual approach is made to measure the intelligence. Here the brain functions are measured through MRI scans. Although intelligence might not be a direct result of the measurement of these brain functions, the difference in brain functions can still be seen as some sort of cognitive ability. Higher brain activity when making decisions could possibly be an indicator of higher intelligence. With a lot of conclusions based on IQ tests and experiments

designed to measure cognitive ability, the addition of biological functions provide a new type of possible evidence and should definitely not be neglected.

In Fudenberg & Levine (2011) a model is created to reflect the importance of self-control and cognitive load. The model is based on a paper previously written by the same researchers. In this model a conflict is created between the long term preferences and the short term preferences of the person. What preferences get most utility is determined by the cost of self-control. Through the model it is found that when the stakes of a lottery are high, the influence of the cognitive load is low, and thus a more rational approach is taken to the decision. This approach reduces the likelihood of phenomena like the Allais paradox happening. The model thus predicts that an Allais paradox is more likely to happen for small probabilities. The time preferences are thus taken as an indicator of rationality and intelligence.

In Choi, Kariv, Mülle & Silverman (2014) the measurements do not include any measurements of intelligence but rather factors that are associated with intelligence. These factors are: gender, age, completed education, household income, occupation, and household composition. Not all of these factors are relevant for this research, but some could influence the cognitive ability of the subject. This paper tests whether there are unobserved effects of education which could influence the choices of the subject. It is assumed in this paper that unobserved effects of education are positively related to observed effects of education. These unobserved effects of education could possibly be seen as the cognitive abilities of the subjects, for higher intelligence leads to an increased chance of higher education.

The most frequent measurement of intelligence is unsurprisingly the IQ test. While the tests used often differ among researches the results give a solid basis of measurement that can be related to risk attitude. The use of different measurements of intelligence can also be seen as a positive development. Should the result of the researches with different measurements be similar the evidence for a relation between risk attitude and intelligence which can be pulled from those results would only be stronger. However these differences in measurements of intelligence sometimes make it difficult to compare the results of the researches. Not all researches focus on the same components of risk attitude. However through the combined knowledge of these conclusions enough data can be gathered to gain insight into the relation between intelligence and several risk attitude components.

4. Comparing measurements of risk attitude

Risk attitude is not a single variable; it is the combination of several components. The components I will consider include likelihood insensitivity, risk aversion, and inter-temporal decision making. Because these components are so different, many different kinds of tests are used in papers to study the behavior of people when facing risk. The comparison and analysis is thus vital in order to make relate these components to intelligence. As mentioned before, the likelihood insensitivity or Inverse-S is the risk attitude component in the spotlight. In papers often tests are designed to measure the likelihood insensitivity or components of risk attitude. The way these test are constructed differs among papers. Each component requires its own way of measurement and testing. Because the test are created differently, the results could also vary. In Frederick (2005) the subjects partake in a test which measure risk attitude by asking questions where they have to choose between a hypothetical gamble and a certain choice. The gamble would give a large gain or loss, and the certain choice would give a lesser gain or loss. To make it more difficult for the subjects the answer with the highest expected value was not always the same. Sometimes the gamble had the higher expected value and sometimes the certain choice. Through this test the attitude to risk as a whole can be measured, as well as the difference in attitude towards risk when facing gains or losses. This test is not very extensive but creates clear results on the risk preferences of the subjects, which then can be related to cognitive ability.

In Brandstätter, Kühlberger & Schneider (2002) it is argued that the overweighting of extreme outcomes (Inverse S) may be caused by the surprise that comes with the extreme outcome and the extra utility or disutility caused by the surprise. Three experiments are conducted in this paper. In the first experiment the subjects are faced with a gamble and after witnessing the outcome of the gamble their happiness was measured through a questionnaire. The second experiment had a similar form , where the subject were told to express their surprise and excitement after being told that they had won a large amount with a 1 percent chance of winning. The third and final experiment relates more to the Inverse S shape. Participants had to make choices between a decreasing certain option and a risky option. This way it could be seen when the subject switched to the risky option. This way the certainty equivalent of the gamble for the subject could be found.

This was repeated for different probabilities so that each probability had its own certainty equivalent. By comparing the certainty equivalent for each probability the shape of the function was often found to be inverse S. This is then related to the level of happiness and surprise in the paper. Experiments in this paper are done with hypothetical incentives, not real incentives. Because of this the emotions caused by the surprise gains or losses are anticipated emotions. Whether the emotions would be

more extreme or less extreme when the experiments would be done with real payoffs is difficult to tell. Questions could be asked whether the result of this paper would truly hold in a real scenario instead of an experiment.

A similar test is conducted in Burks, Carpenter & Rustichini (2009). Here the subject are also faced with a gamble and a certain choice. However here the gamble has the same reward for each question and the certain option has an increasing reward. Again this way the certainty equivalent is measured and in this paper the certainty equivalent for each subject is related to the score on cognitive tests. In Charupat, Deaves, Derouin, Klotzle & Miu (2013) a survey is conducted where the risk attitude of the subjects is measured. Again through decreasing the certain option the conductors of the survey found the certainty equivalent of the subject and could relate this to the intelligence. As mentioned in the theoretical framework it is seen that finding the certainty equivalent of a subject is a quick way to gain insight to the overall attitude towards risk. Benjamin, Sebastian & Shapiro (2013) also finds the certainty equivalent in a way comparable to these previous papers.

Dohmen, Falk, Huffman & Sunde (2010) is another example where the certainty equivalent is taken to see whether a subject is risk seeking or risk averse. Risk attitude is however not the only thing studied in this paper. The inter-temporal choices are also taken into account in this paper. To test the patience of the subjects they were faced with different payoffs with different waiting periods. They had to choose between receiving a payoff right now or a higher payoff one year later. Here the higher payoff was steadily increasing which again creates a point where subjects would switch to the option where the payoff is gained one year later. This creates different levels of patience for the subjects.

Taylor (2013) uses a similar way to find risk attitude. While certainty equivalents are not used, the risk attitude of the subjects is determined by letting them choose between different gambles. The subjects have to choose between a risky gamble and a safer gamble; they have to do this ten times. The point where the subjects switch from the safer gamble to the riskier gamble gives the indication of where the risk attitudes of the subjects lie. It can thus be seen that this method is very close to the use of the certainty equivalent to find risk attitude, it could be argued that the methods are virtually the same. The difference is in the fact that with the certainty equivalent the subjects have to choose between a certain option and a gamble. In this paper the subjects must choose between two gambles, where one is more risky than the other. Whether this influences the results is doubtful, thus the results of this paper should be comparable to other instances where the certainty equivalent is used.

In Eckel, Grossman, Johson, de Oliveira, Rojas & Wilson (2012) the subjects have to choose between different gambles. Each gamble is a fifty-fifty gamble between two payoffs. These combinations of these payoffs are different for each gamble. The gambles are all ranked in risk and variance. This way the choice of the subject reveals their attitude towards risk. If the subject chooses the gamble with the least variance he is risk averse. In this paper the certainty equivalent is not taken into account. Instead the writers choose to keep the test as simple as possible with the argument that increased complexity of a test increases the chances of mistakes made by subjects which would make the results less valid. In this test the expected value for each gamble is easily calculated, this reduces the chance of mistakes happening through miscalculations. Another reason for the increased simplicity of the test is that the tests are performed at schools. For adolescents the effect of a more complicated test might be more significant for the results when compared to adults. This could be due to the fact that adolescent do not yet posses the mathematical skills to fully comprehend more complex problems. Even though the certainty equivalent is already a relatively simple way to measure risk attitude Eckel, Grossman, Johson, de Oliveira, Rojas & Wilson (2012) opt for a simpler test.

In Bleichrodt, Doctor, & Stolk (2005) a part of the paper is dedicated to investigating to a variable that which causes small probabilities to be overrated and high probabilities to be underrated. Likelihood insensitivity has the same effect on probability weighting as the encountered variable in Bleichrodt, Doctor, & Stolk (2005). The variable causes the preferences of the subjects to change, and thus a correction is made in order to find the 'true' preferences of the subjects. The change this correction causes can be studied in order to find information about likelihood insensitivity.

Gonzalez, Dana, Koshino, & Just (2005) focuses on the difference between brain functions for losses and gains. In order to investigate what processes are happening in the brain while making decisions the researchers let the participants face 10 problems. Both problems were represented twice, once in a positive frame and once in a negative frame. The problems the participants faced were common problems which are used to evaluate risky decisions, such as the Asian disease problem. In each of these problems the participant could choose either take a certain gain or loss, or take a risky choice and have a larger gain/loss or no gain/loss at all. Both these choices have the same expected value, thus if the participants are completely rational it should not matter for them what they choose. The researchers chose to put some rest time between each choice made by the participant. This way the brain functions could be measured in an efficient way. The attitude towards losses and gains is thus obtained through this simple test. The measurement of brains functions gives a different insight into the process of decision making when facing gains or losses.

In Einhorn & Hogarth (1985) a model is created that is called an Anchoring and adjustment strategy, where an assessment is formed by a first judgment (the anchor) and adjustments from that anchor. With this model the writers try to explain the choices of people when facing different levels of ambiguity. The model is tested through several experiments to prove whether the model holds. In one of these experiments a possible effect of cognitive abilities is discussed. The model also provides concepts for likelihood insensitivity. The model creates a solid view of the attitude towards ambiguity, as well as proof for likelihood insensitivity. The model use of this model is complicated, however, it provides a different kind of proof for likelihood insensitivity and possible relations with cognitive abilities.

Gayer (2010) also uses a model, however it different than the one used in Einhorn & Hogarth (1985) .The model created in Gayer (2010) is used to find what the impact of consistency is when deciding between different lotteries. The model uses three variables to determine the impact on the choice of lottery: The risk of the lotteries, the consistency of the subject, and the similarity between the lotteries. With the consistency and the similarity of the lotteries a function is created to determine how the subject determines the probabilities of the lottery. The assessment of probabilities is central in this paper. The perception of probabilities is not the same as risk attitude, but it could be debated that different perceptions towards probability could have great influence on the risk attitude of someone. The perception of probabilities does however directly relate to the inverse S. The assessment of how probabilities are perceived is thus a positive addition to find a relation to intelligence, or in this case consistency. A different kind of model is used in Fudenberg & Levine (2011). In this model a conflict is created between the long term preferences and the short term preferences of the person. What preferences get the most utility is determined by the cost of self-control. The model in the paper is very complex and it is of no added value to fully explain it.

It can thus be seen that the most often used way to measure risk attitude is the use of the certainty equivalent. The certainty equivalent could however be influenced by the design of the experiment and the way the lotteries are presented. This could create a bias in some of the results found in these papers. If there is a bias in the results it would make the comparison between papers less valid. In case of the inverse S investigates test for the certainty equivalent do not provide enough information for conclusions, for the certainty equivalent only measures the attitude towards risk and not the under- or overweighting of probabilities. The research of the likelihood insensitivity requires more information to give valid conclusions. This is why often models are used. The complexity of the models makes it more difficult to relate the results to papers where a different method is used to find results. Models and the use of the certainty equivalent make up the most of the investigated

papers' methods. Only a few use different ways to find risk attitude, with the use of the fMRI scan as an interesting method.

5. Relating different components to intelligence

5a. Likelihood insensitivity

Linking likelihood insensitivity to cognitive skills is relatively new in behavioral economics. Therefore there are as of yet not many researches that look into this possible relation. If a relation of inverse S and cognitive functions could be found this could have interesting implications for behavioral economics. The likelihood insensitivity is as mentioned before influenced by the perception of probabilities. With this in mind the best way to find a relation is to start with this in mind. As discussed in Gayer (2010) likelihood insensitivity is related to consistency. The effect of consistency is an interesting factor that is included in the analysis of rIsk attitudes. Gayer (2010) found that consistency has an effect on subjects trying to analyze probabilities. Greater consistency with great similarity among lotteries leads to decisions that come closer to the expected value of the lotteries, thus making the decisions more rational. Gayer (2010) relates their findings to different comparable researches done before on this subject. The findings are related to different effects seen regularly in behavioral economics, such as the certainty effect and the availability heuristic. The discussion part rules out that the effects seen in the results are caused by the certainty effect or the availability heuristic. While it could be that these effects create a certain bias in the results, it still would not fully explain the findings. Therefore it can be concluded that the effects found are caused by the consistency of the subjects. The subjects which make more rational decisions are thus less influenced by likelihood insensitivity. If consistency is influenced by intelligence, a relation between rationality and intelligence can be found. While consistency might be influenced by intelligence, this paper does not prove a direct relation. It does however provide a basis to build the relation between likelihood insensitivity and intelligence.

A relation between cognitive skills and likelihood insensitivity is found in Bleichrodt, Doctor, & Stolk (2005). The authors believe that cognitive abilities influence the people's decision and thus they make a correction in their data. No measurements of cognitive abilities are used, it is merely argued that the limitations of cognitive abilities are the cause of biases in the subjects' decision making. The term likelihood insensitivity is not used in the paper; the effect is dubbed insensitivity to group size. While the name is different the effect described is essentially the same as likelihood insensitivity. The effect causes small probabilities to be overestimated and large probabilities to be underestimated. The study does not explain the nature of the relation; it merely states that the insensitivity to group

size is a result of the cognitive functions of the subjects. More information is required to find whether the relation is positive or negative in nature. Another paper where a relation is noticed is Brandstätter, Kühberger, & Schneider (2002). According to Brandstätter, Kühberger, & Schneider (2002) the surprise is a factor when making decisions on lotteries. The effect of the surprise can be seen as a cognitive function of people. The surprise is not the same as intelligence but can be seen as a an effect of behavior and cognitive functions. The conclusions that likelihood insensitivity can be caused by cognitive functions created by a surprise gives an interesting lead up to the relation between likelihood insensitivity and cognitive skills.

A recent study that does directly look at cognitive functions is Petrova, van der Pligt, & Garcia-Retamero (2014). They find that for possible gains there is more likelihood insensitivity then when facing possible losses. It is argued that the factors hope and fear play an important part in the cause of the differences in likelihood insensitivity for gains and losses. Thus it is found that emotions have an influence on the weighting of the probabilities. Numeracy was also a factor which was tested for. It is found that increased numeracy leads to better probability weighting. This leads to a lesser inverse S in the probability weighting graph. The relation between the effect of emotion and the numeracy is not discussed in this paper. The result that increased numeracy leads to a lesser inverse S shape for the probability weighting curve is very informative for a relation to intelligence. Higher intelligence often leads to a higher degree of numeracy.

With these few studies it is difficult to prove a direct relation between the likelihood insensitivity and intelligence. The results of the discussed papers do not exclude a relation between the two variables. Quite the opposite can be seen in the results of these papers. The variables consistency, surprise, emotions and numeracy are seen as factors which have an influence on the probability weighting and the shape of the inverse S curve.

All of these factors are cognitive functions or related to cognitive functions and some can be related to intelligence. The factors consistency and numeracy could be heavily correlated with intelligence. The effects of surprise and emotions is not as heavily related to intelligence but could still be related in a lesser extent. The relation is thus difficult to prove directly, but with the factors discussed having influence on the likelihood insensitivity of people it is highly likely that it should be only a matter of time until it is unveiled that intelligence is a factor which influences likelihood insensitivity.

5b. Risk Aversion

Risk aversion is a concept which has been around much longer than likelihood insensitivity. Because of this there is more research available where risk aversion is related to intelligence. As discussed this is most often done through the use of certainty equivalents. This is then related to the score of people on intelligence tests. Frederick (2005) created an intelligence test with real incentives which is used in more papers. The results of these papers are thus easily compared. Frederick (2005) found that the results on risk preferences are varying. The group with high test for intelligence scores was less risk seeking for losses. However they are more risk seeking in terms of gains compared to the groups with lower scores. Frederick (2005) found that the scores on the intelligence test is related to the risk preferences of the subjects. However to fully explain the nature of the relation more proof is required.

Dohmen, Falk, Huffman, & Sunde (2010) is another instance where risk aversion and intelligence are investigated in a similar way, through the use of an IQ test and certainty equivalents. Real payoffs are used the experiment. It is found that people with lower cognitive ability have higher risk aversion when dealing with gains. The experiment only gives possible gains, thus no results are found on risk aversion when dealing with losses. Interesting to note is also the variables which are controlled for in the regression. The IQ test consists of two parts: a numeracy test and a word fluency test. The scores of the test are related to the risk preferences when they are looked at separately and when they are combined. The relation between cognitive ability and risk attitude also persists while controlling for variables such as: Characteristics, education and income. The cause of the difference in risk preferences is thus not created by these variables but come from the difference in cognitive ability.

Burks, Carpenter, & Rustichini (2009) do look at the difference between gains and losses. Again real incentives are used. They find that higher cognitive skills lead to a higher willingness to take calculated risks when facing gains. The treatment of gains and losses is thus affected by cognitive abilities. Subjects with high cognitive abilities are more risk seeking for gains and risk averse for losses, while subject with a lower cognitive ability are more likely to be risk seeking for losses. This causes the subjects with higher intelligence to stay closer to expected value when facing either gains or losses. Lastly it is found that subjects near risk neutral behavior have higher cognitive abilities than subjects with less risk neutral behavior. These findings align with the previous findings of Frederick (2005) as well as the findings of Dohmen, Falk, Huffman, & Sunde (2010).

Benjamin, Sebastian, & Shapiro (2013) finds that higher cognitive ability is related to less risk aversion when dealing with gains and lower cognitive ability is related to more risk aversion when

dealing with gains. The experiments in this paper use hypothetical rewards and only gains are taken into account. These papers use the same method of finding results and thus the fact that the conclusions are similar reinforces the conclusion that a relation exists between risk preferences and intelligence.

Gonzalez, Dana, Koshino, & Just (2005) investigates the cognitive processes in the brain when facing gains and when facing losses. In this case real payoffs are used in the experiment. The main result found in this research is the difference in brain activity for negative and positive framing situations. In positive framing situations the cognitive functions measured differed greatly for the risky choice and the certain choice. The activity in the brain is higher when taking a risk for gains. In the negative framing situation the opposite effect occurs. When taking the certain option for the losses the brain produces higher activity compared to the activity for the sure loss. The results prove that cognitive processes are of great influence on the decision making of people. The difference between high and low cognitive ability is not discussed, however assuming that cognitive abilities affect cognitive processes a relation is found between cognitive ability and the perception of risky situations.

Eckel, Grossman, Johnson, de Oliveira, Rojas, & Wilson (2012) find differences in risk attitudes for people with different length, gender, and skin color. An experiment is used with hypothetical payoffs. Cognitive ability is also investigated and here there is no relation between risk attitude and cognitive ability, this contrary to the previously discussed papers. The difference in results could have several possible causes; some of these are discussed by Eckel, Grossman, Johnson, de Oliveira, Rojas, & Wilson (2012). They ascribe the difference in results to the simplicity of the way IQ is tested. The subjects in this paper are high school students and the cognitive ability is tested through a math literacy test. However previously it is discussed in the paper that the math test is a valid way of testing cognitive ability. Other factors which may be the cause of the difference in results being found could be the influence of the school environment. It is found in the paper that students which attend high schools where the average income is low have a higher risk aversion for gains. The effects of the school environment on risk preferences are possibly stronger than the effect of cognitive ability. Another cause might be that the cognitive ability is not the main variable investigated. The result still provides an interesting discussion point, as the method used to find it is valid. Whether the cause of the difference is age of the subjects or the school environment is not the most important. It can be concluded that in different situations the effect of cognitive ability on risk preferences can be different.

Taylor (2013) is another instance where differences related to cognitive abilities are found. The paper finds that subjects with high cognitive ability are more risk seeking for gains in hypothetical situations compared to situations with real incentives. These results might explain the differences found in some of the other papers. Not all experiments use real payoffs. The finding that cognitive ability is only related to intelligence in hypothetical situations might make the conclusions of these papers less valid. It is argued that the cause of this might be that subjects with high cognitive ability view the lotteries with hypothetical payoffs as puzzles, where they have to seek the correct solution. When including real payoffs this changes and the subjects with high cognitive ability revert to more risk averse behavior for gains.

Hawes, DeYoung, Gray, & Rustichini (2014) also find a relation between risk attitude and intelligence. In their results they find that the relation is not merely a learning process, where previously experienced outcomes influence the decision making on decisions in the future. They find that the experience of outcomes for lotteries is different for subjects with different IQs. When the experience of outcomes is different it can be assumed that this also influences the decision making and risk preferences. Hawes, DeYoung, Gray, & Rustichini (2014) however do not discuss the nature of this relation. It is merely concluded that a relation exists through the difference in experience of outcomes.

Barreda-Tarrazona, Jaramillo-Gutierrez, Navorro-Martinez, & Sabater-Grande (2011) is another study that looks at real and hypothetical situations with relation to risk attitude. It is found that subjects were less risk averse when payoffs were real compared to when payoffs were hypothetical. They conclude that tests with hypothetical payoffs instead of real payoffs can give misleading results on risk attitude. Slovic (1969) reinforces the conclusion that real and hypothetical situations produce different results. The conclusions based on test with hypothetical payoffs might thus give different results for those with real payoffs. Most of the previously discussed papers use real incentives , so the findings that intelligence influences risk attitude might very well still be true.

Another result of no relation is found through a simple math literacy test. As previously discussed the writers argue that this is due to the simplicity of the test. However, I feel all possible viewpoints of this relation should be discussed. Not all measurements used of intelligence are very complicated, so why would the result suddenly be different in this particular case. The result is found for younger people (high school attendees) and this might be an influence on the risk attitude as well. Intelligence might not be a great influence at an earlier age. This is all however an assumption and cannot be backed by further proof. The arguments in favor of a relation between risk aversion and intelligence are far more numerable.

The conjecture that a relation only exists in hypothetical situations is rejected by several papers which use real incentives in their experiments and still find results which indicate a relation between risk attitude and intelligence. Not all of the papers however define the nature of the relation and only state its existence. Those that do find a relation do not always have the same results. However the findings for people with lower intelligence are usually the same: Lower IQ leads to more risk averse behavior when dealing with gains. Higher Intelligence is more related to risk neutral behavior This is because more intelligent people tend to follow expected value more than lower intelligent people do. Because of this the willingness to take calculated risks in order to gain a higher expected value increases.

5c. Time preferences

Time preference is not truly a part of risk attitude, but many of the encountered papers include consistency or patience in their research which is why it is included in this thesis. While time preferences are in the context of risk, the behavior for different levels of intelligence could still provide information for components of risk attitude. The time preferences are related to the discount rates of people. When measuring discount rates subject have to choose between two payoffs, one right now and one at a later point in time. The value of the later choice is often higher so the decision depends on how high the discount rate of a person is. Assuming that staying close to the expected value can be seen as rational behavior, how close different levels of intelligence stick to the expected value could tell something about how rational their behavior is. This can then be related to risk attitude components. There are far more researches who investigate this possible relation, however only the ones that also involve risk attitude in their research are studied in this thesis.

Frederick (2005) not only related cognitive ability to risk attitude but also to time preferences. The results support the theory that cognitive ability has influence on time preferences. It is found that higher scores on the intelligence test are related to more patience when it comes to the time preferences. Benjamin, Sebastion, & Shapiro (2013) also find that higher intelligence is related to behavior that is more patient. The higher intelligence group followed the expected value of the choices more than the group with lower intelligence. Burks, Carpenter, & Rustichini (2009) also find a relation between intelligence and time preferences. They also find that subjects with a higher IQ tend to be more patient in receiving payoffs. It is argued in that the higher patience could be caused by a better control of impulsivity of the higher IQ subjects. This theory is however not confirmed.

Dohmen, Falk, Huffman, & Sunde (2010) also find the same result, higher cognitive ability is positively related to patience. These papers all find the same result and have the same conclusion: Higher intelligence increases the patience of people. While this conclusion is not very surprising it can still be related to risk attitude. The behavior for time preferences of higher intelligent people can be seen as more rational. As said before it is assumed that following expected value when making decisions is seen as rational. The main finding that is important for this research is that intelligence is a factor for decision making. The conclusion that intelligence has influence on decision making in relation to time creates a more complete picture of intelligence on decision making.

6. Discussion

The most frequent conclusion amongst all components is that cognitive ability has an influence on risk attitude. While some papers argue against a relation, most of the evidence points towards a relation between risk attitude and intelligence. For likelihood insensitivity however more proof is required to remove any doubt that a relation exists. While some evidence is found, it is not enough to fully define the relation between the likelihood insensitivity and intelligence. Likelihood insensitivity is a relatively new concept in behavioral economics. Therefore there is a limited amount of research where it is related to intelligence. There is a lot of potential for further research on this particular subject . It is also needed to create more proof on whether likelihood insensitivity is related to intelligence.

For the other risk attitude components that are investigated, less potential is present for further research. Most of the studies reach a general consensus on risk aversion and time preferences in relation to intelligence. Even with all the different measurements of cognitive functions the studies come to the same conclusion. Higher intelligence leads to more risk seeking behavior for gains and lower intelligence leads to more risk aversion for gains. Even though there are some who argue against this view the majority of the papers investigated agree with this point of view. For time preference the conclusions are even more similar where the general conclusion of more patience among higher intelligent individuals is generally accepted. The near consensus on these two components mean that further research is less urgent when compared to likelihood insensitivity.

However more evidence with better types of measurement could always find different results, thus it should never be ruled out that the relation between risk aversion/time preferences will hold when

more research is done. As with likelihood insensitivity and most topics in behavioral economics the theories are relatively new when compared to other economic theories. This means that the coming decades could bring new researches and topics that further support or undermine these conclusions. The implications of these results could help understand the behavior and decision making when risk is involved for different types of people. The difference in risk aversion for different levels of intelligence could help in the design of government programs with regards to help for battling gambling addictions and could help explain the behavior of different people in the stock market.

7. Conclusion

The results for likelihood insensitivity do not rule out a relation between risk attitude and intelligence, yet they do not provide enough proof for a relation. Factors such as consistency, numeracy, emotions and surprise reactions have been proved to affect likelihood insensitivity. These factors provide an indication of a relation between likelihood insensitivity and intelligence, yet they do not provide concrete proof.

This is contrary to the other two studied components. For risk aversion the literature indicates that intelligence has an effect. Higher intelligence is related to less risk aversion towards gains. The literature does not provide a consensus on the effect of intelligence on risk attitudes when facing losses. While often a relation is found, the results vary. With this in mind the effects of intelligence on risk aversion must be further investigated in order to create a conclusion on the relation.

The last component studied, time preferences are found to be related to intelligence. More patient behavior is found among more intelligent individuals. For risk aversion and time preference strong evidence is thus found that intelligence has an influence on both these factors. For likelihood insensitivity some factors which could be related to intelligence are found to be correlated with likelihood insensitivity. However together they unfortunately do not provide enough proof to conclude that intelligence is a factor in likelihood insensitivity. Thus further research on this topic is warranted.

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