Stockholm School of Economics
Department of Economics
5350 Master's thesis in economics
Academic year 2015–2016

Reducing cognitive biases through meditation
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Neuroscientific evidence and a model of human capital investment with heterogeneous individuals

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The neuroscientific discovery of brain plasticity indicates that it is possible to improve the performance of certain brain areas by engaging in different kinds of training. Since the literature on human capital has not yet taken into account this kind of investment, this thesis attempts to fill this void by focusing in particular on overcoming cognitive biases. Two aims are followed in this regard. First, to provide neuroscientific evidence that meditation induced brain plasticity can in theory reduce cognitive bias based judgment errors. Second, to investigate how the level of education and the degree of competition influence the willingness of an individual to make such an investment in meditation in the context of a competitive job market, in which decision-making is of particular importance. To this end, a model of human capital investment with individual heterogeneity in education is developed. This model suggests that individuals who, due to their sufficiently high education do not face competition early on in their career, will be more willing to make the proposed investment.

Keywords: human capital investment, brain plasticity, meditation, cognitive biases

JEL: C72, J4, J24

Supervisor:	Chloé Le Coq
Date submitted:	23 May 2016
Date examined:	31 May 2016
Discussant:	Sara Bivebäck
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Definitions

Brain Plasticity:

Plasticity is an intrinsic property of the human brain which allows the brain to overcome restrictions of its own genome in order to adapt to environmental pressures, experiences and physiologic changes and such an alteration of a brain region also corresponds to an alteration of the region's functions (Fox et al., 2014; Pascual-Leone, Amedie, Fregni & Merabet, 2005)

Cognitive Bias:

A cognitive bias is a systematic error in judgment and decision making which arises due to cognitive limitations, adaptations to natural environments and motivational factors (Wilke & Mata, 2012).

Heuristics:

The use of a heuristics in judgment refers to a situation in which an individual assesses a particular target attribute of a judgment object by evaluating another property of that object, the heuristic attribute which comes more easily to mind, instead (Kahneman & Frederick, 2002, p. 53).

Meditation:

Meditation is a form of mental training aiming to improve the core psychological capacities of an individual (Tang, Hölzel & Posner, 2015).

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1. Introduction

While neuroscientists had known that the adult brain can change at the cellular level to encode new facts, changing the size or the function of a given brain area was deemed impossible (Davidson & Begley, 2013, p. 164, Lowenstein & Parent, 1999). However, neuroscientific research in the past two decades proved this former view to be false as the phenomenon of brain plasticity was discovered, which allows for alterations in the structure of the brain. This effect of plasticity can be induced by engaging in either physical (e.g. Draganski et al, 2004) or mental training (e.g. Pascual-Leone et al., 1995). This is of particular interest as an alteration in a specific brain area corresponds to an improvement of this brain area's functions (Fox et al., 2014). However, the possibility for individuals to make such an investment to improve their performance has despite its potential not yet been addressed by the existing literature on human capital. While there are many areas for which a better performing brain could be useful, the most interesting application of brain plasticity is to address flaws in processes of the brain that cannot effectively be tackled by other means.

Such flaws often manifest themselves as evolutionary adaptations. These adaptations originated as the response to evolutionary demands. They do not necessarily constitute an optimal solution to a given problem, but rather the best of the available alternatives (Gilovich & Griffin, 2002, p. 9). It follows that even successful adaptations can have costs (Arkes, 1991). Every evolutionary adaptation has a different origin and the reason why they can create certain costs can be found in the different functions and operations of the brain. As it will be difficult to address all these adaptations at the same time, this thesis will focus on only one particular adaptation, namely on the use of heuristics which leads to the existence of cognitive biases. There are two reasons for this choice. First, the economic relevance of cognitive biases as their occurrence can impose considerable costs in nowadays world. Second, the available evidence, which indicates that addressing the problem of cognitive biases is indeed feasible.

To understand the first reason it has to be noted that while the use of heuristics in decision making is overall beneficial, it at the same time leads to grave and systematic errors (Tversky & Kahneman, 1974). Indeed, the cognitive biases which arise from the use of heuristics can be defined as a systematic discrepancy between the correct solution to a judgmental task, according to a formal normative rule, and a decisionmaker's actual answer to the task (Montibeller & von Winterfeldt, 2015). A vast number of decisions are made each day, which involve especially high stakes in crisis situations. May it be how to correctly react to a natural disaster or how to treat a patient in the emergency room. The potential costs of committing judgement errors due to cognitive biases are accordingly quite high as well. Yet, there is currently little hope to avoid these costs as it is difficult to correct these cognitive biases with existing methods (Monitbeller & von Winterfeldt, 2015). For these reasons, has a new treatment for the reduction of cognitive errors the potential to raise overall welfare considerably.

Concerning the second reason it has to be emphasized that no scientific study has yet been conducted that proves that occurrences of cognitive biases can generally be reduced by inducing brain plasticity. Still there is evidence pointing in this direction. For instance it has been shown that a greater activation of the orbitofrontal cortex reduces the susceptibility to the framing effect, which belongs to the family of affect heuristics (De Martino et al. 2006). Interestingly, the orbitofrontal cortex is also one of those regions that were found to be consistently altered through meditation (Fox et al., 2014). Moreover, when considering how cognitive biases exactly arise and what kind of functions those other brain regions fulfil, which were shown to be consistently altered by meditation, it appears very likely that the practice of meditation has the potential to reduce the occurrence of cognitive biases through inducing effects of brain plasticity. In addition, there are a number of meditation studies reporting an improvement in aspects that appear to be helpful when addressing cognitive biases.

Due to the apparent potential of meditation and the void in the existing research in this regard, the first aim of this thesis is to provide theoretical evidence that a reduction of cognitive biases through meditation is possible. Once it has been established that meditation is likely to have the claimed effect, it is of interest to investigate for which individuals it would be beneficial to invest into practising meditation in order to reduce their judgment errors by avoiding cognitive biases. The demand will not be unlimited as practising meditation also comes at a costs, mainly in the amount of time meditating, and for some individual it might yield more benefits than for others. However, the existing economic literature on human capital investment provides no answer to this question. In order to find out for which individuals investing into meditation might be worthwhile, a new model of human capital investment is developed in this thesis. It models individuals with heterogeneous levels of education competing for well-paid but scarce jobs, for which decision-making is of particular importance. These individuals face the choice of whether to further invest in their level of human capital and if so, in which of two possible skills they wish to invest. One of these two skills resembles an investment into meditation and it is the second aim of this thesis to answer the following research question:

How does the level of education of an individual and the level of competition in the job market influence the willingness of an individual to invest into meditation to reduce the occurrence of cognitive biases in the context of a competitive job market, in which decision-making is of particular importance?

The thesis is structured as follows. To outline the research problem in greater detail the current shortcomings in the economic literature on human capital investment are described in Section 2. In addition, the Section will further explain the research question, outline the strategy applied to address it and briefly discuss the limits of this thesis. The first aim of this thesis is then addressed in Section 3. In a first step it will be outlined what is described by the term cognitive biases and why these biases occur. Once the concept is understood, it will be explained which methods were applied to address this problem so far, before the evidence that meditation can reduce the occurrence of cognitive biases is presented in a second step. This Section concludes with a discussion on the reliability of meditation research as this field is still rather young. After the evidence provided in the former Section ensures a practical relevance of an analysis of the proposed investment possibility, Section 4 addresses the research question and the second aim of this thesis. To understand the context of the research question a description of the relevant job market will be given. Then the developed model of human capital investment is introduced. There are two versions of the model. The first features only one investment opportunity for individuals and serves the function of highlighting which mechanisms and factors determine the decisions of the individuals. The second includes meditation as an alternative investment and shows when this investment opportunity is chosen. To analyse the two versions of the model they are translated into an economic game. The results from the game are then discussed and generalized for the model. In Section 5 a discussion follows on the insights and limits of the presented model and its relation to the existing literature. Moreover, the contribution of this thesis will be discussed and suggestions for further research given, before Section 6 concludes.

2. The Research Problem

2.1. Motivation

When the economic literature became first involved in analysing the investment into an individual's productivity, the theory of capital was applied to the decisions of individual improvement to explain observed educational and occupational choices (Ben-Porath, 1967). In this research field of human capital two of the theories developed in the 1960s and 1970s remain influential today. However, they differ significantly in their underlying assumptions regarding the productivity of investments into human capital. The human capital theory developed by Becker (1962) rests on the assumption that investment in on-the-job training and schooling will increase productivity. It is further assumed that the increase in productivity stems from learning new skills and improving old ones (Becker, 1962). In this context, schools and universities are seen as institutions which engage in the production of training for one or more skills (Becker, 1962). The signalling model of Spence (1973) can be seen as a competing model of the human capital theory. In contrast to Becker's work, Spence (1973) builds his model on the assumption that education does not increase productivity and only signals the level of innate productivity of the respective worker. In its extreme form, this line of literature assumes that there is no learning content in schooling (Cunha, Heckmann, Locher & Masterov, 2006, p. 700). Nowadays, the reasoning of Becker (1962) still serves as a basis for economic models of family influence and the idea of an inalterable, innate ability in the theory of Spence (1973) is still the prevailing assumption in most quarters of economics (Cunha et al., 2006, p. 700).

When these models were developed, the current wisdom in neuroscience was that the human brain was capable of changing at the cellular level, where the strengthening of the connections between neurons encoded new knowledge and skills (Davidson & Begley, 2013, p. 164). This reasoning backs up the argument made by Becker (1962) to a certain degree as it allows for some improvement. However, the dogma in neuroscience was also that the brain and its macrostructure were inalterable (Lowenstein & Parent, 1999) and any changes regarding improving the functions of a certain brain region were considered impossible (Davidson & Begley, 2013, p. 164). This point of view strengthens those who consider the innate ability of people to a large degree inalterable. While the latter assumption still appears to prevail in economics, the dogma in neuroscience has changed dramatically in the past two decades due to the discovery of the effect of brain plasticity, which can result in an improved functioning of the altered brain areas (see Draganski et al., 2004; Hyde et al., 2009; Nudo, Milliken, Jenkins, Merzenich, 1996; Pascual-Leone et al., 1995). Hyde et al. (2009) for example showed that musical training leads to alterations in the brain which are correlated with improvements in auditory and motor skills. In the area of mental training, it has been shown among other things that meditation influences the subject's intelligence (Sedlmeier et al., 2012), which is particularly important as the IQ represented the inalterable innate ability in the traditional literature on human capital formation according to Cunha et al. (2006, p. 780). The potential improvement of certain brain functions and the resulting increase in productivity suggests that the underlying assumption of the signalling theory is inaccurate. In contrast, the fundamental assumption in human capital theory has been strengthened as it has been shown that practising skills can lead to an improvement. Yet, in the light of the new insights from neuroscience the assumptions made by Becker (1962) also remain incomplete. While his theory covers the investment into learning or improving new skills, it neglects the possibility to invest into altering the brain in general and does not take the potentially resulting benefits into account. This neglect is understandable given that the success of such an investment was deemed impossible at the time. However, the assumptions in the field of human capital formation have not changed much in the meantime as pointed out earlier. Instead, on the microeconomic level the research in the field has focused on the role of family income (e.g., Aiyagari, Greenwood & Seshadri, 2002; Becker & Tomes, 1979, 1986), credit constraints (e.g., Cowan, 2016; Locher & Monge-Naranjo, 2011), noncognitive ability (e.g., Heckman, Stixrud & Urzua, 2006; Schick & Steckel, 2015) and multi-stage investment (e.g., Cunha et al., 2006; Cunha, Heckman & Schennach, 2010). On a macroeconomic level the influence of aspects such as international trade (e.g., Unel, 2015) and public debt (e.g., Greiner, 2016) were meanwhile investigated. While these studies certainly advance the literature, the possibility of investing into an alteration of brain functions remains unaddressed. To decide if this new investment possibility, which could also be understood as a new underlying assumption, requires a change of the existing theories or an addition to the literature it is necessary to evaluate to which degree such an investment can be incorporated in existing frameworks and in which aspects it differs from existing models. There are three cases that need to be distinguished.

The first case describes a situation in which an alteration of the brain structure is related to improving a certain skill through practice. For example has it been shown by Pascual-Leone et al. (1995) that practising to play the piano increases the size of the motor cortex and that this size increase is correlated with the level of improvement regarding the playing performance. Such an alteration of the brain structure is in line with the argument made in the human capital theory that practising a certain skill leads to an improvement. The phenomenon of brain plasticity merely provide a better explanation why exactly practice results in an improvement. This does not change Becker's theory as the input and the expected output remain the same. The resulting decisions will therefore remain the same as before and no change in the theory is needed in this regard.

It is also possible that individuals could attempt to use brain plasticity in a multi-stage investment setting. The advantage of first investing into an alteration of the brain is that all those investments that will be made in later stages will become more efficient. This gain in future efficiency lies in the improved performance of some brain areas which may help to make future training less costly or more efficient. While such an optimization choice would be interesting to analyse, the theoretical foundations have already been laid in human capital formation theories through the introduction of the concepts of self-productivity and complementarity of investments in multi-stage investment decisions (e.g. Cunha et al., 2006; Cunha et al., 2010). Hence, the new investment could be incorporated in these existing theories. However, not enough research regarding brain plasticity has been conducted yet to accurately analyse such as choice.

The third case describes a scenario which has already been introduced in the previous Section, namely that a brain alteration could address the operational flaws in the brain which manifest themselves in certain situations and arise due to otherwise beneficial evolutionary adaptations. The key difference to the first case is that these flaws cannot be addressed by more practice. In contrast to the second case, overcoming these operational flaws are not necessarily meant to make other future investments more efficient. These two points can be further illustrated by considering the example of reducing cognitive biases. While one might be tempted to consider it as a skill, which could be understood as a skill in decision making, the systematic nature of the errors separates the reduction in cognitive biases from the general skills considered in case 1. In Becker's theory training leads to an improvement in the given skill, but this does not seem to be the case for decisions affected by cognitive biases, precisely because the committed errors are systematic. By making numerous decisions one might improve the quality of the decision due to having more experience. Yet, the use of heuristics will not be overcome by employing them more often. Regarding the second case it has to be pointed out that the reduction of cognitive biases does not have the purpose of making future investments in individual improvement more efficient, the purpose is to address a certain problem now.

Since the evolutionary adaptations in case 3 tend to have unique reasons for the existence which can be found in the different functions and operations of the brain, it will not be feasible to address them all in one approach. Instead, this thesis will focus on addressing the problem of cognitive biases for the reasons outlined in the introduction. In general, such an investment in a reduction of cognitive biases has the potential to avoid many wrong decisions that are taken each day and that negatively affect people worldwide. By addressing the weaknesses in our own system we can not only increase our own efficiency, but also contribute to an improvement of the lives of other people as all too often affected by our decisions.

2.2. Research Question and Strategy

Even if reducing the occurrence of cognitive biases is possible through meditation induced brain plasticity, it does not automatically follow that individuals will choose to make such an investment. Since there is a cost involved in altering the brain, in the form of engaging in training, the demand for such a measure will not be unlimited and in general individuals will only choose to invest if it is beneficial for them to do so. To understand whether an individual makes the proposed investment it is therefore crucial to specify in which setting such a decision would be considered beneficial and which factors influence the additional utility an individual could expect from investing.

The literature on human capital is mainly interested in how a higher level of human capital leads to a higher wage and in the individual's investment choices to maximize his life-time income (see e.g. Mincer, 1958, Becker, 1962, Ben-Porath, 1967). Since reducing cognitive errors through practising meditation can be considered as an investment in an individual's human capital in the area of decision making, it is of interest how such an investment will affect the chances of an individual to secure a higher paying job when decision making constitutes a predominant task of the profession. The investment decision will therefore be analysed in a setting where a number of individuals compete for scarce but well-paid jobs and have the opportunity to make strategic investments into different types of skills.

Education constitutes another factor which is assumed to define an individual's ability to make good decisions. It is important to note that meditation is considered a complement to education rather than a substitute for it. Meditation improves the quality of decisions on top of the existing ability to make the right choices indicated through the level of education of an individual. In the population this level of education varies considerably between individuals. Based on this observed heterogeneity this thesis addresses the following research question:

How does the level of education of an individual and the level of competition in the job market influence the willingness of an individual to invest into meditation to reduce the occurrence of cognitive biases in the context of a competitive job market, in which decision-making is of particular importance?

The research question will be addressed by developing a model of human capital investment with heterogeneous individuals and using its insights to answer the stated question. This procedure involves several stages. In the beginning, the labour market in which decision making constitutes a crucial aspect is described and the key features will form the basis of the model. In the end, the model represents a labour market in which a number of individuals compete for well-paid but scarce jobs and these jobs are allocated based on the level of human capital accumulated by these individuals. Individuals feature heterogeneity in their education level and can make strategic choices to increase their level of human capital. Two versions of the model will be presented, which differ in the number of investment alternatives for the individual. In the first version of the model, the investment choices are limited to investing or not investing in a particular skill in order to investigate which mechanisms generally determine the investment behaviour of the individuals with different education levels. In the second version, an additional layer of competition is introduced, as those individuals, who successfully secured one of the well-paid jobs in the first round, compete to receive a promotion involving a bonus payment in a second round. Moreover, individuals in this model have two investment alternatives to increase their human capital. Investing in the first offers to reach a higher human capital in the short run than investing in the second, but choosing the second investment alternative will lead to a higher human capital level in the long run. In this setting the second investment alternative resembles an investment in mediation, while the first can be understood as a competing skill which is considered to be preferred by firms when first hiring applicants. The purpose of this second model is to reveal which individuals will choose the long-term and which the short-term investment and which constraints limit their choice. In order to find the equilibrium behaviour of the individuals with the different education levels and to highlight the strategic choice the individuals are facing, the two versions of the model are translated into two economic games. In each game there will have nine players. Three players always have the same level of education. In the game with one investment alternative, a variation in the number of available well-paid jobs constitute different versions of the game. In the game with two investment alternatives, the number of versions of the game grows further by introducing an additional variation in the number of available promotions. The solution concept of iterated elimination of strictly dominated strategies (IESDS) is applied to find the iterated-elimination equilibrium. After the choices of the individuals with different education levels are known for the different versions of the game, it will be analysed if general patterns regarding the investment behaviour exist in the game. These insights will be used to generalize the conditions for the equilibrium from the game to the model before the general conclusions from the model are drawn.

Before conducting this economic analysis in Section 4 it is necessary to limit the scope of this thesis and to outline in Section 3 why the current state of knowledge in neuroscience suggests that the underlying assumption, that meditation leads to an alteration in the brain resulting in a reduction of cognitive biases, is very likely to hold to ensure that the following steps have a practical relevance.

2.3. Limits of the study

While the available data from meditation research points in the direction that altering the brain's structure is capable of reducing the occurrence of cognitive biases, no scientific study has yet shown that this claim generally holds beyond addressing a single particular bias. Conducting such a study is desirable, but beyond the scope of this thesis as it would require more resources, equipment and time than available. In addition, such an endeavour would pursue a different aim than this thesis, which is mainly concerned with the economic consequences of possibility to reduce cognitive biases. Since it is important nonetheless for this thesis to show the potential of brain plasticity in addressing judgment errors, available scientific data will be analysed theoretically, instead of collecting new evidence empirically, to show that the aforementioned claim is very plausible.

Given the wide scope of the research on cognitive biases a few more limitations are necessary. There is the tendency to divide biases in the two categories, cognitive biases and motivational biases (see Montibeller & van Winterfeldt, 2015). This thesis will only examine cognitive biases as the effects of brain plasticity have consequences for the structure and functioning of the brain itself. In contrast, it likely has little effect on motivational biases which arise to different reasons. If for example an individual has a vested interest in coming to a certain conclusion a better functioning brain will not rid this individual from falling for the confirmation bias in this situation. Even though there is an extensive list of cognitive biases supplied by research, no particular bias will be addressed when considering the potential of meditation, but rather the group of cognitive biases. The reason is that they mainly arise due to the same processes in the brain. If this process can be addressed in general, there is no need to focus on a particular bias. Moreover, this thesis focuses on the investment of the individual and therefore group biases will not be considered either.

3. Reducing Cognitive Biases through Meditation

In Section 2 the concept of brain plasticity has been shortly introduced as the reason why the assumptions previously made in human capital formation theories are either inaccurate or at least incomplete. Based on the assumption that changing the structure of the human brain is possible, it has been argued that flaws in evolutionary adaptations can be addressed and that this thesis in particular will investigate for which groups of individuals it will be beneficial to make an investment into a reduction of judgment errors. Up to date, no scientific study has proven in a general fashion that practising meditation can reduce the occurrence of cognitive biases as these studies tend to be more interested in medical treatments. Yet, the existing evidence strongly suggests meditation has the claimed potential. Since the relevance of the economic analysis depends on the correctness of the underlying assumption, this Section will use the current state of neuroscientific and psychological research to argue that the underlying assumption, that cognitive biases can be addressed through brain plasticity, is reasonable.

The concept of cognitive biases will be explained in the first Section. This includes a review of what are considered to be a cognitive biases, which brain operations lead to their existence and which ways have been found so far to address them. The second Section will then outline the existing evidence for the claim that meditation induced plasticity can address those shortcomings which lead to the existence of cognitive biases. Since it is crucial to understand the concepts of brain plasticity and meditative practice, both will be briefly introduced before two types of evidence are offered for the above mentioned claim. The first approach is based directly on the effect of brain plasticity and investigates which brain areas are consistently altered through meditation and how an improvement of the functions of these regions should theoretically lead to less judgment errors through cognitive biases. The second approach focuses on meditation studies in general and summarises which effects have been found after the practice of meditation that back up the findings of the first approach as well as outline the findings of those studies that already made the link between meditation and cognitive biases. The Section concludes with a discussion on the reliability of findings from meditation research.

3.1. An Introduction to Cognitive Biases

3.1.1. What are Cognitive Biases?

A cognitive bias can be defined as a systematic error in judgement and decision-making, which is common to all human beings and arises due to cognitive limitations or adaptations to certain environments (Wilke & Mata, 2012). The systematic nature of the errors is the main distinction to the rational choice model, in which a rational actor assesses the probability of each possible outcome, considers the utility derived from each and then pursues the option that offers the optimal combination of probability and utility (Gilovich & Griffin, 2002, p. 1). While advocates of the rational choice model do not claim that calculative mistakes do not occur, they insist that those errors are unsystematic (Gilovich & Griffin, 2002, pp. 1-2). However, when it comes to decision making under uncertainty Tversky and Kahneman (1974) point out that people are relying on a limited number of heuristics which help to reduce complex tasks such as predicting values or assessing probability to simpler judgmental operations. Despite their benefits these heuristics can also lead to grave and systematic errors (Tversky & Kahneman, 1974).

In general, these systematic errors occur because people tend to answer an easier question when confronted with a difficult one, usually without being aware of it (Kahneman & Frederik, 2002, p. 53).

In more scientific terms, a judgment is said to be mediated by a heuristic when an individual assesses a particular target attribute of a judgment object by assessing another property of that object, the heuristic attribute, instead, because it comes more readily to mind (Kahneman & Frederick, 2002, p. 53). Since the heuristic attribute and the target attribute are different, substituting one for the other inevitably results in systematic bias (Kahneman & Frederik, 2002, p. 53). While this is especially relevant for decision making under uncertainty, heuristic processing data leads to judgment errors in general, when the assessment of probabilities or prediction of future values are not involved.

In their original work Tversky and Kahneman (1974) describe three types of heuristics that are employed in making judgments under uncertainty as well as the biases that result from employing the respective heuristics. The first heuristic is representativeness, which is often employed when it is necessary to judge the probability that an event or object A belongs to process or class B. The probability is then assessed by the degree to which A represents or resembles B. This process leads for instance to insensitivity of prior probability of outcomes and sample size. Availability is the second heuristic that is described and it is often employed when the frequency of an event or the plausibility of a development needs to be assessed. In these cases the frequency or likelihood of an event or development is evaluated by the ease that such instances are brought to mind, which leads for example to biases based on the retrievability of instances. The last heuristic is adjustment and anchoring, which describes the effect when an available value influences a numerical prediction. Later Kahneman and Frederik (2002, pp. 56-57) argue, however, that anchoring does not fit the definition of judgment heuristics presented above, because it is not based on substituting one attribute for another. Instead it works by increasing the plausibility of a given value of the target attribute. Kahneman and Frederik (2002, p. 56) therefore propose that an affect heuristics should replace anchoring in the list of general heuristics. It turns out that every stimulus evokes an affective evaluation, which may occur outside of awareness. Since affective valence is a natural assessment it is in many situations an area for substitution and therefore the affect heuristic fulfils the requirement of attribute substitution.

Arkes (1991) discusses the costs that arise due to a successful adaptation of heuristics and offers a taxonomy of judgment errors based on the nature of these adaptational costs. According to him there are three types of judgment errors, which he calls strategy-based errors, association-based errors, and psychophysical based errors. Strategy-based errors occur when a suboptimal strategy is used to solve a problem. While this procedure saves time and effort, a reduced accuracy of the solutions constitutes the costs of this habit. The association-based errors are based on the system of associations within the semantic memory and occur when the automaticity of such associations brings irrelevant or counterproductive semantic associations to mind when making a decision or a judgment. A heightened retrievability can thus result in nonveridical estimates of an event’s frequency or probability. Biases that constitute association-based errors are for instance the confirmation bias, representativeness and overconfidence. Psychophysically based errors occur due to a nonlinear mapping of physical stimuli onto psychological responses. While a nonlinear map has the advantage to not need to discriminate small changes in rare events, this diminished sensitivity at the extremes also constitutes a costs. The sunk cost effect, anchoring and framing, are manifestations of this particular cost.

While many studies have found evidence for the existence of certain biases (see Kahneman, Slovic & Tversky, 1982; Gilovich, Griffin & Kahneman, 2002), the relevant questions for this thesis are why do these cognitive biases arise and how can their occurrence be prevented or their frequency be reduced. As described above, Tversky and Kahneman (1974) and Arkes (1991) have given some answers regarding the first question. The next Section will examine the first question further by explaining how the brain is assumed to make its decisions.

3.1.2. Why do Cognitive Biases arise?

The answer to the question why cognitive biases arise can be found in the way how our brain operates. The concept of the dual-process theory (see Hammond, 1996; Sloman, 1996; Chaiken & Trope, 1999) is widely accepted and even though the existing models are slightly different, they generally feature two different cognitive operations, one is quick and associative and the other slow and rule governed (Kahneman & Frederick, 2002, p. 51). Following the generic labels of Kahneman and Frederik (2002) and Stanovich and West (2002), this thesis will refer to the first operation as System 1 and to the latter as System 2. System 1 is described by Stanovich and West (2002) as automatic and heuristic-based requiring relatively little computational capacity. System 2 by contrast is considered to feature those characteristics associated with controlled processing (Stanovich & West, 2002, p. 436). In this model it is assumed that System 1 puts forward intuitive answers when given a judgement problem and System 2 monitors the quality of the offered proposals and if necessary corrects them (Kahneman & Frederick, 2002, p. 51). In light of the dual-process theory there are two relevant questions regarding the occurrence of errors in intuitive judgment. First, which features of System 1 is responsible for committing an error. Second, why does System 2 not detect and correct such errors.

According to Stanovich and West (2002, p. 436) the main mechanism behind System 1's failure is the tendency of an automatic contextualization of problems. By transferring a neutral problem into a given context, the likelihood increases that an associations with this context will be used as the heuristic attribute replacing the target attribute, which might have no connection to the chosen context at all. The contextualisation therefore leads to the employment of the availability, affect and representativeness heuristics. In contrast, System 2 tends to decontextualize and depersonalize problems and can hence avoid errors in judgment (Stanovich & West, 2002, p. 436). While according to Kahneman and Frederik (2002, p. 51) System 1 and System 2 can be active at the same time and address the same problem simultaneously, the response from System 1 will be the first one available due to the quicker processing. System 2 may override this response of System 1, but this procedure requires effort as Kahneman and Frederik (2002, p. 57) point out. A depletion of cognitive resources can therefore lead to a premature response becoming the final one as Gilbert (1991) explains. As a consequence cognitive load can disrupt the control function of System 2 and increase the error rate (Kahneman & Frederik, 2002, p. 57). Time pressure has the same effect (Kahneman & Frederik, 2002, p. 58). It is important to note though, that individuals differ regarding the ability of their System 2 to override the response primed by System 1, because only the system 2 processes of some individuals have enough computational power or low enough threshold for their activation (Stanovich & West, 2002).

In the previous Section attribute substitution was identified as the underlying feature of heuristic processing of information that leads to errors in judgement. With the input from the dual-process theory it can be further specified under which conditions attribute substitution will control our judgment. According to Kahneman and Frederik (2002, p. 54) this will occur if the following three conditions are satisfied. First, relative inaccessibility of the target attribute. Second, high accessibility of an associatively and semantically related attribute. Third, substituting the heuristic attribute into the judgement is not rejected by critical reflection of System 2.

To summarise, there are several reasons why cognitive biases occur in judgment and decision making. The first reason is the automatic contextualisation of a problem in the operation process of System 1, which leads to the employment of heuristics and hence systematic judgment errors. The underlying feature of these heuristics is the substitution of attributes. While this is the case for problems in general, it appears especially pronounced when making decisions under uncertainty, indicating that people struggle in particular with assessing probabilities. The weakness of people to address probabilities correctly can be seen as another reason for cognitive biases. A third reason is the failure of System 2 to detect an error. While the consequence of detecting the error would be to not give a response at all, giving the correct response requires System 2 to correct the response given by System 1. Since such a process requires effort, scarce cognitive resources due to cognitive load or time pressure are therefore reasons for errors in judgment. Another reason is found on the individual level. When System 2 processes do not have the requisite computational power or the activation threshold for their employment is too high, an erroneous response of System 1 cannot be overridden. From the taxonomy of judgment errors two more reasons follow. The first is using a suboptimal strategy rather than a more sophisticated one to solve a problem. The second is the psychological nonlinearity of maps that leads to diminished sensitivity at the extremes.

3.1.3. How can Cognitive Biases be addressed?

According to Kahneman and Frederik (2002, p. 68) the two following elements can reduce the employment of the representativeness heuristic. The first is statistical sophistication. Experts in statistics are more likely to follow logic than intuition in comparison with the statistically naïve. The second characteristic is intelligence, because individuals endowed with a high IQ benefit from relatively efficient System 2 operations, which enables them to override an erroneous response from System 1 when adequate information is available.

Research has also been conducted regarding the question how individuals can train themselves and which tools they can use to reduce the occurrence of errors in their judgment. This approach is called debiasing and refers to the attempt to eliminate or at least reduce cognitive biases (Montibeller & von Winterfeldt, 2015). One of the most recent studies is Montibeller and von Winterfeldt (2015), which provides an extensive list of known biases in decision and risk analysis as well as debiasing methods for them. In categorizing cognitive biases the authors proceed in two steps. First, it is stated for each biases to which error type it belongs according to the taxonomy of Arkes (1991). It has to be noted here, that while Arkes (1991) believes the term bias is not appropriate for strategy-based errors, Montibeller and Winterfeldt (2015) regard strategy-based errors as a cognitive bias. Since the strategy-based-errors do not have their origin in attribute substitution (Arkes, 1991), it is not surprising that Monibeller and von Winterfeldt (2015) find that strategy-based errors can be much easier corrected than the other groups of errors by employing the use of analytical models. In the second step of the categorization, the association-based and psychophysically-based errors therefore form the group of biases which are difficult to correct, while the strategy-based errors form the group of cognitive biases that are easy to correct.

Among the easily correctable cognitive biases are for instance the base rate neglect and the insensitivity to sample size and according to Montibeller and von Winterfeldt (2015) these biases can be addressed as follows. To address the base rate neglect it is proposed to split the task into two parts, an assessment of the base rate for the events and the likelihood ratio of the data given the events. Using statistics to determine the probability of extreme events is considered to address to bias of insensitivity to sample size. In general, the debiasing approaches used to correct the cognitive biases in this group are based on using logical models to address certain problems, splitting the assessment of probabilities in two separate tasks and educating subjects in basic statistics (see Montibeller & von Winterfeldt, 2015). Among the biases that are difficult to correct are for example overconfidence and omission of important variables. To address the overconfidence bias the provision of probability training and challenging extremes through the use of counterfactuals is suggested and the proposed mechanism for omission of variables is to ask for extreme scenarios and prompting for alternatives and objectives (Montibeller and von Winterfeldt, 2015). While biases in the easy to correct group could be mainly addressed through the use of logic and decomposition, there appears to be no overall solution strategy for the difficult to correct group. Instead, the debiasing methods are more unique for the different biases. At the same time, enhancing statistical knowledge and asking for alternatives or counterfactuals appear to be used to address a number biases (see Montibeller & von Winterfeldt, 2015). The former method is in line with the work of Kahneman and Frederik (2002), while the latter method is an addition to it. In general, it should be kept in mind that the biases in this group are difficult to correct according to Monitbeller and von Winterfeldt (2015) indicating that the success of their proposed debiasing strategies is still limited.

A completely different approach is to investigate whether financial incentives can reduce judgment errors based on rationality violations. After reviewing 74 studies Camerer and Hogarth (1999) conclude that there is no replicated study which eliminated rationality violations purely by raising incentives. Arkes (1991) points out that associate-biases cannot be reduced through incentives as the motivated subjects will only perform the suboptimal behaviour with greater enthusiasm. Moreover, incentives are ineffective in reducing psychologically based errors (Arkes, 1991). For real cognitive biases, which are based on attribute substitution, financial incentives do therefore not work. This makes sense as automatic process in the brain do not change by offering an individual more money. The case is different for the family of the strategy-based errors, which are characterised by the use of a suboptimal strategy, because in those cases where effort is crucial, Camerer and Hogarth (1999) find that monetary incentives have an effect. Still, this thesis is more concerned with the other two groups which are more difficult to correct.

To summarise, research has shown that several aspects can reduce the occurrence of cognitive biases. Three aspects are of particular importance in that regard. First, the familiarity and knowledge of statistics and probabilities. Second, the intelligence of a subject as a higher intelligence facilitates the ability of System 2 to override erroneous responses. Third, counterfactual reasoning and the search for alternatives. In the next chapter evidence will be given that suggest that engaging in meditation also has the potential to reduce or even eliminate the occurrence of cognitive biases.

3.2. Addressing Cognitive Biases through Meditation induced Plasticity

3.2.1. A short History of Brain Plasticity

Brain plasticity can be defined as an intrinsic property of the brain that allows for a change of the brain’s structure to adapt to environmental pressures, certain experiences and physiological changes (Pascual-Leone et al., 2005). There are two effects that fall under the term brain plasticity that need to be distinguished.

The first effect is that a certain brain area changes its previous function and becomes responsible for different tasks. This phenomenon was first observed in monkeys as certain brain areas changed their original function due to a lack of sensory feedback (Pons et al., 1991). Similar changes were the observed in humans. The brain region responsible for visual sight of blind people for instance changed from its originally intended function to processing signals from reading the tactile writing-system Braille (Röder et al., 1999). Also after suffering a stroke the task of the damaged brain regions can be taken over by other brain regions, which served a different purpose before (Taub et al., 2006).

The second effect describes a training induced structural change in a certain brain area and a corresponding improvement in the execution of its functions, which, in contrast to the first presented effect, remain the same as before. This is the effect of brain plasticity this thesis is mainly interested in. Hence, if the effect of brain plasticity is mentioned in the following, it refers to this second effect. The described effect was also first observed in monkeys as the brain area representing the fingertips increased in size as a result of special finger exercises (Nudo et al., 1996). Draganski et al. (2004) later show that plasticity can also be induced in humans by teaching them how to juggle as an expansion of grey matter in the regions associated with processing and storage of complex visual motion was detected in the treatment but not in the control group. The authors also found a close relationship between the increase in grey matter and the juggle performance, indicating that the more grey matter in a certain brain area corresponds to an improvement in its function. While the previous study relied on physical practice Pascual-Leone et al. (1995) showed that mental practice is sufficient to induce plastic changes in the brain. The authors conducted an experiment in which one treatment group practised playing the piano physically for five consecutive days while another treatment group engaged in the same task, but only mentally. The different treatments led to a similar increase in the size of the cortical motor area as well as a significantly improved playing performance. In their review and meta-analysis Fox et al. (2014) note that there is in general fairly robust evidence for the connection between the structure and the function of a brain region. Fox et al. (2014) therefore conclude, that an alteration of a specific brain area entails a corresponding alteration in its function. It is important to note, that in early research an alteration of a brain area refers to an increase in size of the brain area, while later research understands this as an expansion in grey or white matter in the given area. The reason for this difference is the available technology.[1]

From these findings two conclusions can be drawn. First, mental activity can induce plastic changes in the brain and increase certain brain areas. Second, an increased size of a brain area corresponds to an improvement in its function. Given the possibility of achieving the effect of brain plasticity through purely mental activity considerable research has been done in the past decade to investigate how meditation can alter the brain's structure. The first study that found that meditation is associated with structural brain changes was Lazar et al. (2005) and up to date more than 20 studies have found meditation induced structural alterations in the brain structure (Tang, Hölzel & Posner, 2015)

3.2.2. A short Introduction into Meditation

Meditation can be defined as a kind of mental training, which aims to improve the core psychological capacities of the meditator (Tang et al. (2015). However, the specific meditations techniques can vary considerably in aims, difficulty and scope as Fox et al. (2014) point out. Varying levels of difficulty can

[1] The earlier studies used for example a technique called cortical mapping, in which different areas of the scalp are stimulated with a magnetic stimulator and based on these stimulations conclusions could be drawn regarding the structure of the brain (e.g. Pascual-Leone et al., 1995). In contrast, more recent studies used for instance voxel-based morphometry, a technique which allows to investigate changes in grey and white matter in a certain brain region through three dimensional magnetic-resonance imaging (e.g. Draganski et al., 2004).

for instance be found in Zen meditation as beginners usually count their breaths to focus their attention, while more advanced practitioners stop counting and aim for an undirected awareness of present experiences (Chinesa & Malinowski, 2011). In contrast, Insight meditation follows a different aim as it explicitly focuses on body sensations (Fox et al., 2014). In general, the different techniques can be distinguished according to which mental faculties they use, how they use these faculties and the objects to which these faculties are directed as Sedlmeier et al. (2012) explain. The most well-known categorization scheme, however, divides different meditation types into concentrative and mindfulness techniques (Cahn & Polich, 2006).

Concentrative techniques, also known as focused attention practices, originally stem from Hinduism and involve directing one's attention at a single object of meditation, which may be one's breath, the recitation of a certain phrase or an actual physical object (Fox et al., 2014). Sedlmeier et al. (2012) add that by for instance focusing on the breath, meditators reach a state of heightened awareness and experience how the mind jumps around different thoughts. After becoming aware of this, the meditators learn to not engage in responses to these thoughts, emotions or other cognitions, which produces a calming effect (Sedlmeier et al, 2012).

Mindfulness techniques, also known as open monitoring practices, originally stem from Buddhism and involve a receptive and non-judgmental attitude towards any kind of experience (Tang et al., 2015). These techniques emphasize remaining present in the moment and to not allow the mind to engage in chains of associations or wander into the past or the future as Sedlmeier et al. (2012) explain. With enough practice meditators should become aware of their thought patterns without reacting to them and eventually just observe thoughts, feelings or sensations (Sedlmeier et al, 2012).

While these techniques appear quite distinct in theory it is according to Sedlmeier et al. (2012) difficult to place a meditation technique exclusively in one of the two presented classes as in practice virtually all meditation techniques use a combination of concentration and mindfulness. For instance, Tang et al. (2015) argue that the technique called mindfulness-based stress reduction consists of both focused attention and open monitoring elements. Moreover, most experienced meditators tend to have substantial experience with different techniques (Fox et al., 2014). Since these meditators often keep some elements of previous techniques when switching to a new meditation technique, Sedlmeier et al. (2012) conclude that in practice meditation might not exist in a pure form at all. Following this line of reasoning, it becomes obvious why it is difficult for studies to study the neural basis of the two presented categories separately and even harder to do so for a particular technique (Fox et al., 2014). Indeed, in Fox et al.'s (2014) analysis many studies have mixed practitioners from multiple traditions. Since these studies form the basis of conducted meta-analysis and reviews, which in turn form a substantial part of the evidence for the claims made in this thesis, it was not possible to limit the scope of this thesis to one particular meditation technique.

3.2.3. Theoretical Evidence based on Neuroplasticity

It would be possible to look at the over 20 studies that have reported meditation induced plasticity individually and take into consideration which brain areas were affected in each study. However, it constitutes a more reliable approach to consider those brain areas in more detail, which have been found to be consistently altered through meditation, as these results are less dependent on the specific setting of an individual study and the exact meditation technique employed. Due to this reasoning, the effect of meditation induced brain plasticity on cognitive biases will be mainly be evaluated in this Section based on the recent meta-analysis conducted by Fox et al. (2014).

Fox et al. (2014) reviewed 21 neuroimaging studies, which fulfilled certain methodological criteria and reported alterations in different brain regions. An anatomical likelihood estimation (ALE) was used to investigate if there are certain brain regions which are consistently altered through meditation. The authors find this to be the case as the ALE meta-analysis shows that eight brain areas were consistently altered in meditators. At least three of these areas, namely the rostrolateral prefrontal cortex, the orbitofrontal cortex and the anterior cingulate cortex, fulfil functions which are linked to the processing of information and decision making.

As has been observed earlier, an alteration of a brain area, in terms of an increase in its size or the expansion of grey or white matter, is correlated with an improvement of its function (see Draganski et al., 2004; Hyde et al., 2009; Pascual-Leone et al., 1995; Fox et al., 2014). Since the brain areas identified by Fox et al. (2014) consistently show such an alteration, it follows that their respective functions should also improve. In the following, it will be outlined for each of the three brain areas mentioned above, how such an improvement in their functions can contribute to a reduction in judgment errors. To this end, the relevant functions of a brain area will first be explained. Whether an improvement in these functions can reduce errors in judgement will then be judged by building upon two types of insights gained in the previous Sections about cognitive biases. First, it will be investigated if the improved functions are capable of addressing the flaws in the assumed functioning of System 1 and System 2 according to the dual-process theory. Second, it will considered if the improved functions can contribute to aspects that have shown to reduce biases, namely an improved handling of statistics and probability, a higher intelligence as well as counterfactual thinking and search for alternatives can reduce the occurrence of cognitive biases.

3.2.3.1. The Rostrolateral Prefrontal Cortex

The first relevant region that was found to be consistently altered through meditation is the rostrolateral prefrontal cortex (RLPFC)/Brodmann Area (BA) 10 (Fox et al., 2014). The authors report that the ALE meta-analysis found a trend level cluster in the region and that an alteration has been reported in three other studies. Since the meditation technique in these three studies varied from Insight to Tibetan Buddhist and Brain Wave Vibration meditation, Fox et al. (2014) conclude that structural changes in RLPFC can be generalized beyond any meditative practice. The RLPFC is activated when people engage in complex cognitive tasks such as reasoning (Christoff & Gabrieli, 2000; Christoff, Ream, Geddes & Gabriele, 2003). The more complex a given task is, the more likely it is that the RLPFC is recruited (Christoff, Keramatian, Gordon, Smith and Maedler, 2009). The RLPFC is especially used to evaluate internally generated information (Christoff & Gabrieli, 2000). An example for this kind of self-generated information is an individual's plan for solving a problem (Christoff et al., 2003). In addition, the RLPFC is also involved when evaluating information that needs to be inferred as it cannot be easily perceived from an external environment (Christoff et al., 2003). Moreover, the RLPFC is responsible for relational integration (Christoff et al., 2001), performs deductive operations (Monti, Osherson, Martinez & Parsons, 2007), facilitates the meta-awareness of one's own thoughts (McCaig, Dixon, Keramantian & Christoff, 2010) and is in general responsible for processing complex and abstract information (Christoff et al., 2009).

That the recruitment of the RLPFC increases with rising complexity of a task suggests that the RLPFC is part of the operations of System 2. This is in line with the findings of Fox et al. (2014) that meditation generally recruits more higher-order brain regions. It can therefore reduce judgment errors through increasing the use of System 2, because an improved processing of information should lower the threshold for the recruitment of System 2 as it makes it more efficient in term of energy required. If System 2 is active more often, the likelihood of it detecting errors and correcting them increases. To override an erroneous response of System 1 it is necessary that System 2 finds the correct answer for the problem. By improving the evaluation of information, the relational integration and deductive operations an improved functioning of the RLPFC increases System 2's capabilities of finding the correct solution. Thus it reduces judgment errors by enabling System 2 to replace an erroneous answer more frequently. A third way how the enhanced RLPFC contributes to a reduction of judgment errors is by potentially increasing the detection of errors. The consequence of a better functioning RLPFC is an improvement of the evaluation of internally generates information, which include solution plans to a problem and therefore also most likely the responses suggested by System 1. Due to a better evaluation more erroneous proposals should be detected. On the same line, due to a greater meta-awareness of one's thought, people should realize more often when they use a suboptimal solution strategy to address problems.

Kahneman and Frederik (2002, p. 68) have argued that a higher IQ leads to a reduction in judgment errors due to more efficient System 2 operations. An improved processing of information should make the operations of System 2 more efficient. Therefore a better functioning of the RLPFC can be regarded as the equivalent to the higher IQ. Using counterfactual thinking and searching for alternatives was pointed out as one method to address cognitive biases that are difficult to correct. A better integration and evaluation of information should increase the likelihood of searching for alternatives as more information is available to point to them and a better evaluation might lead to a more critical assessment of existing options and hence the necessity of an alternative.

To summarise, five reasons were pointed out why an improvement of the RLPFC's function has the potential to reduce errors in judgment. The first three have to be seen in the light of the dual-process theory and here errors can be reduced through a more frequent activation of System 2, an improved reasoning of System 2 as well as an improved ability to detect erroneous proposals by System 1. The other two reason belong to the area of the debiasing literature and state that improving the processing of information is similar to a higher IQ as both make System 2 operations more efficient. In addition, a searching for alternatives is facilitated by a better integration and evaluation of information.

3.2.3.2 The Orbitofrontal Cortex

The second relevant region that was found to be consistently altered through meditation is the right orbitofrontal cortex (OFC) (Fox et al., 2014). The authors report that the ALE meta-analysis found a significant cluster in the region. Moreover, the OFC showed activation for instance in Shamatha, a type of focused attention meditation and loving-kindness meditation. The OFC is particularly active when it is required to make choices with insufficient information (Elliott, Dolan & Frith, 2000). It then provides the ability to integrate all information in real-time to make predictions or estimates about future outcomes (Schoenbaum & Esber, 2010). This becomes especially important when past experiences are insufficient to predict the occurrence of an outcome correctly (Schoenbaum & Esber, 2010). With rising complexity of the prediction task the activation of the OFC increases, indicating that the OFC is especially important when difficult decisions need to be taken (Elliott, Rees, Dolan, 1999). It is also plays a crucial role when the selection of the appropriate action is based on the knowledge of the probabilistic contingencies (Elliott et al., 1999). Moreover, the OFC is involved in counterfactual reasoning (Schoenbaum & Esber, 2010), self-monitoring (Beer, Sohn, Scabini & Knight, 2006) and when it is necessary to interpret somatic sensations when making a decision (Beer et al., 2006). Fox et al. (2014) add that the OFC is also responsible for the integration of cognitive cues in decision making.

From the functions outlined above it can be concluded that the OFC is involved in making decision under uncertainty. In these circumstances the representativeness and availability heuristics are likely to be employed by System 1. The fact that the OFC is recruited when facing insufficient information suggests that it plays a role in the operations of System 1. At the same time, an increase in activation with the growing complexity of a problem also indicates that OFC is also a part of the operations of System 2. An improvement of the functioning of the OFC would translate to an improvement in the ability to deal with probabilities as the OFC is responsible for predictions and estimates of future outcomes and selecting the right action based on probabilistic contingencies. A better ability to cope with probabilities and uncertainties might reduce the necessity for System 1 to substitute the target attribute with the heuristic to find a solution, because the target attributes would be better understood and there is less need for its substitution. For System 2 an improved ability to work with probabilities would increase the chances of finding the correct answer, which can then in turn override the previously erroneous answer of System 1. In addition, an improved integration of cognitive clues might increase System 2's ability to detect errors in previous reasoning.

Kahneman and Frederik (2002, p. 68) explain that statistical sophistication reduces errors in judgment. The OFC appears to be in the process of finding solution when statistical knowledge is involved, because it is playing an important role in selection the right action based on the probabilistic contingencies. While improving the functions of the OFC cannot teach subjects statistical rules, it has the potential to help them to better apply these rules by improving the estimates of future outcomes and the understanding of situations with insufficient information in general. Since the OFC is involved in counterfactual reasoning, an improvement of this function should enable people to use counterfactual thinking better and more frequently, which should lead to the avoidance of cognitive errors according to Montibeller and von Winterfeldt (2015).

To summarise, there are five reasons why improving the functioning of the OFC should reduce judgment errors. In the domain of the dual-process theory, System 1 should be less dependent on substituting attributes as the target attribute should be better understood in decision making under uncertainty. System 2 will also benefit from an improved ability to deal with uncertainty as the correct answer will be found more often and thus an erroneous response can be overridden. Moreover, the integration of cognitive cues might facilitate error detection. While improving the OFC cannot increase statistical sophistication through learning the statistical rules, it may still contribute to a higher sophistication by supplying a better understanding of the probabilities and improving the quality of estimates. The OFC might also enhance counterfactual thinking, which was identified as one debiasing method.

3.2.3.3. The Anterior Cingulate Cortex

The last region of interest that was consistently altered through meditation is the anterior cingulate cortex (ACC) (Fox et al., 2014). The authors report that two significant clusters were found in the region in the ALE meta-analysis and that three studied have reported alterations in the region. That these alterations were found different meditation techniques such as Zen, IBMT and Brain Wave Vibration meditation indicates that the region is altered in general through meditative practices. There is a large amount of evidence suggesting that error detection and monitoring constitutes an important function of the ACC according to Bush, Luu and Posner, 2000) and Beckmann, Johansen-Berg and Rushworth (2009) show that the region is active during error detection. Rushworth, Walton, Kennerley & Bannerman (2004) confirm that error detection is part of the ACC's role and point out that the ACC does not only predict which outcome is expected from a certain action but also if the action may lead to an error. This is in line with Brown and Braver (2005) findings that the ACC learns to predict error likelihood in a given context. The ACC is also involved in action selection, where it plays a fundamental role in relating certain actions to their expected consequences (Rushford et al., 2004) and in making cost-benefit decisions (Rushford, Behrens, Rudebeck & Walton, 2007). In addition, it is activated when presented new information, indicating its influence on decision making (Behrens, Woolrich, Walton & Rushworth, 2007). Other functions of the ACC include outcome monitoring (Rushford et al., 2007), executive attention (Posner, Rothbart, Sheese & Tang, 2007) and recruiting cognitive control (Brown & Braver, 2005). Fox et al. (2014) summarises that the ACC is linked to insightful as well as focused problem-solving, error-detection and decision-making in general and that the ACC plays an important role in a situation in which the value of actions is uncertain or rapidly changing and when it becomes necessary to consider multiple pieces of information discern the optimal behaviour.

There is some potential in reducing errors in judgment by improving the functioning of System 1 through a better understanding of the relationship between an action and an outcome as well as a better understanding of values under uncertainty, which might reduce the necessity to use heuristics. However, the main potential of an improvement in the functions of the ACC lies in the operations of System 2. An error in judgment occurs when System 2 fails to detect an erroneous response given by System 1. Since detecting errors is a main function of the ACC, an improved ACC should enhance the ability of System 2 to detect errors and thus reduce the occurrence of judgment errors. While System 1 is constantly active and automatically addresses decision problems, System 2 has to be recruited for that task. Since the ACC is responsible for recruiting cognitive control, improving this function might enable System 2 to be recruited more often, especially when facing a decision under uncertainty as these situations are prone to cognitive biases. Next to the activation of System 2, an improved functioning of the ACC can also improve the capacity of System 2 to find the correct answers to problems as the ACC is plays a role focused problem-solving, cost-benefit analysis and dealing with new and multiple pieces of information.

To summarise, there are four reasons why an improvement in the functions of the ACC can lead to a reduction in judgment errors. Regarding System 1 it might increase the quality of its responses. It also affects System 2 in three ways. First, it potentially increases its recruitment increasing the chances that it overrides errors. Second, the quality of its operations might improve and thus lead to more erroneous responses being replaced with correct ones. Third, its ability to detect errors made by System 1 increases and thus the rate of errors in judgment decreases.

3.2.4. Theoretical Evidence based on Meditation Research

3.2.4.1. Meta-Analysis regarding Psychological Variables

Sedlmeier et al. (2012) conducted another meta-analysis of meditation studies, but instead of focusing on brain plasticity the authors investigated which effect meditation has on psychological variables. To this end, the authors reviewed 163 meditation studies and transferred the dependent variables used in these studies through coding into 133 dependent measures, which were summarised into 21 categories forming the different psychological variables. For the meta-analysis the authors used a random-effect model developed by Hunter and Schmidt (1990, 2004). Concerning the potential of reducing cognitive biases through meditation the reported effect size of two categories are noteworthy. For cognition the authors find an effect size of 0.28 and for intelligence an effect size of 0.22. The authors base their work on Cohen's (1992) conventions, which means that the effect for cognition can be considered medium sized and the effect for intelligence small to medium sized.

An improved cognition should lead to a better functioning of System 1 and 2 as discussed in previous Sections. Based on the information provided by the meta-analysis it cannot be deducted though for which of the two systems the effect should be more pronounced. An increase in intelligence should also reduce errors in judgment as Kahneman & Frederick (2002, p. 68) point out that more intelligent people benefit from more efficient operations of System 2, which enables them to overrides erroneous responses from System 1 more often.

3.2.4.2. Conflict Monitoring

In their review about the current stage of research regarding mindfulness meditation Tang et al. (2015) point out that several studies report that conflict monitoring has improved as a result of meditation. This is relevant, because conflict monitoring is closely related to the supervising functions of System 2 and an improvement in this function can hence lead to a reduction of judgment errors. After a theoretical analysis, two studies finding this effect in practice will be outlined in greater detail.

Conflict monitoring is also referred to as executive control and constitutes, next to alerting and orienting, one of the three networks in the attention system of the human brain as put forward by Petersen and Posner (1992, 2012). The function of the executive network is to resolve conflicts between multiple responses originating in different brain areas (Tang et al., 2015; van den Hurk, Giommi, Gielen, Seckens & Barendregt, 2010). An example for such a situation is the Stroop test, in which subjects have to report the colour in which a colour word is written (`blue` is written in yellow), as subjects make associations when reading the word and the challenge is to overcome the word-reading response (Botvinick, Braver, Barch, Carter & Cohen, 2001). The function of conflict monitoring is according to Botvinick et al., 2001) to translate an occurrence of such a conflict into an increase in cognitive control to resolve the conflict. This can be understood as a signal to System 2 to become engaged in a task to override erroneous proposals.

A reduction in errors due to an improved conflict monitoring was also found in practice. Van den Hurk et al. (2010) conducted a study to test if meditation leads to improvements in attentional processing and compared the performance of 20 meditators and age- and gender-matched controls in the attention network test. They report better executive attention, measured in error rate and response time, and conclude that extensive meditation is related to reduction of errors for responses with the same reaction time (van den Hurk et al., 2010). This finding again indicates a better functioning of System 2 regarding error detection due to meditation. Instead of comparing meditators to non-meditators, Tang et al. (2010b) conducted a longitudinal study to investigate the effect of meditation on attention and to this end taught non-meditators the IBMT meditation technique for 5 days. A comparison of pre-post treatment showed that the meditation treatment led to an improvement in conflict monitoring as indicated by the attention network test (Tang et al., 2010b). Both studies underline the potential of reducing cognitive biases through meditation via an improved ability to monitor conflicts.

3.2.4.3. Individual Studies

Up to date, only two studies have investigated the effect of mindfulness and meditation on cognitive biases (see Sun, Yao, Wei & Yu, 2015). Kiken & Shoot (2011) report a reduction of the negativity bias and Hafenbrack et al. (2014) found that meditation reduces the sunk-cost bias. Both addressed biases can be placed in the category of psychophysically-based errors in the categorization of Arkes (1991) and are not based on attribute substitution, but on the evaluation of information. Yet, reducing these biases has the potential to lower errors in judgment. Moreover, a third study by De Martino, Kumaran, Seymour and Dolan (2006) will briefly be presented as it reports that greater activation in the OFC reduced the susceptibility to the framing effect.

It has been long known that negative information is often weighted more heavily than positive information as shown for instance by Gilovich (1983) in the domain of gambling. This tendency to give greater weight to negative information is referred to a negativity bias (Kiken & Shoot, 2011). Kiken and Shoot (2011) investigated the effect of mindfulness, the state reached through meditative practice, on this bias by comparing the results of different treatment groups from task of correctly classifying positive and negative stimuli, which serves as an objective measure of negativity. The authors report that the results of their experiments suggest a bias reduction for the group engaging in meditative breathing exercises.

Hafenbrack et al. (2014) investigated the potential of meditation to reduce the sunk cost bias through a series of experiments. The sunk cost effect refers to a cognitive bias that consists of taking past investments into account when making prospective decisions (Montibeller & van Winterfeldt, 2015). First, the authors tested the relationship between mindfulness and the resistance to the sunk cost effect by asking the subjects to complete the Mindful Attentional Awareness Scale and the Resisting Sunk Cost subsection of the Adult Decision-Making Competence Inventory. A regression analysis of the generated date showed that mindfulness is a significant predictor for resisting the sunk cost bias. While the first experiment was just correlational, the authors conducted two further experiments to show that this effect results from meditative practice. After receiving a brief meditation instruction subjects had to answer an economic decision making problem featuring the sunk cost. When comparing the results to a control group, the resistance to the sunk cost bias was significantly higher in the treatment group. The second experiment replicated these results with a different decision problem and different subject group and showed the same results.

The framing effect leads subjects to make different decisions in situation in which a question is framed differently but features the same underlying probabilities of events (see Arkes, 1991). The framing effect systematically biases choices and arises due to the use of affect heuristics, which involves attribute substitution, driven by the emotional system (De Martino et al., 2006). When investigating the neurobiological basis of the framing effect, De Martino et al. (2006) discovered that a greater activation in the OFC reduces the susceptibility to the framing effect. As noted earlier, the OFC was one of the eight regions that were consistently altered through meditation, which is generally related to an increase in size and a higher activation. Hence it should follow that meditation leads to a reduction of the susceptibility to the framing effect.

3.2.5. Reliability of Meditation Research

While it has been elaborated above in great detail why meditation is likely to be capable of reducing cognitive biases, the reached conclusion is only as strong as the scientific studies it rests upon. Since research on meditation still constitutes a relatively young research field it is often attacked for instance on the basis of methodological flaws. This Section aims at addressing these criticisms and their consequences for the conclusions reached in this paper.

When summarising the current state of research on mindfulness meditation Tang et al. (2015) summarise the overall criticism as follows. Most studies have not been replicated yet, there is a publication bias to publish significant results and conclusions of findings are often arrived at on an ad hoc basis rather than being based on a unifying theory. In addition, the authors mention small sample sizes in the studies and the low number of longitudinal studies as methodological flaws.

While the lack of replication of individual studies is certainly a valid critique, it does not affect the findings of this thesis to a large degree as the main argument is based on the findings of the meta-analysis of Fox et al. (2014). Since the alterations in the identified brain areas were independently and consistently found in different studies and the ALE meta-analysis it lowers the chances that a non-existent effect was reported in a study considerably. In this thesis little can be done against a potentially existing publication bias. Moreover, the lack of a unifying theory appears to be of little concern for this thesis as the conclusions were not drawn based on an aspect of a certain theory. Instead they were drawn on the basis of which regions were consistently shown to have been altered through meditation and which tasks these regions execute based on the neuroscientific studies which have no link to meditation research.

The problem of methodological flaws in individual studies was addressed by relying on meta-analysis for the drawn conclusions. Basing the results on meta-analysis has two advantages compared to working mainly with individual studies. First, the authors of the used meta studies have excluded methodologically questionable studies in their analysis (see Fox et al., 2014; Sedlmeier et al., 2012). Second, it partly solves the issue of small sample sizes in individual studies. By using multiple studies for their ALE meta-analysis Fox et al. (2014) had a sample size of about 300 meditators for their calculations compared to the 15-20 common in individual studies. While it is true that in the early years of meditation research cross-sectional studies were more common, a number of longitudinal studies have been conducted in recent years, which show alterations in the structure of the brain. Tang et al. (2015) list about ten longitudinal studies reporting plasticity effects after meditation and longitudinal studies were also included in the meta-analysis by Fox et al. (2014). While cross-sectional studies face a causality problem, the existence of the longitudinal studies (e.g. Tang et al., 2010a; Tang et al., 2012) shows through pre-post measurements that meditation indeed increases the size of different brain areas, rather than individuals with enlarged brain areas tending to engage in meditation.

Another aspect which deserves a brief discussion is the difference between statistical significant results and practical significance. In general, it could be possible that even though Fox et al. (2014) found statistically significant alterations in specific brain areas, it does not necessarily mean that these existing differences make any real differences. However, the authors were aware of this problem and therefore also calculated in addition the statistical significance of the results the effect size of the different alterations found in order to get the magnitude of the alterations, rather than the significance of those changes, and report a global medium effect size based on Cohen’s (1992) conventions (see Fox et al., 2014). In addition to these calculations it should be noted that alterations induced through mental training resulted in real improvements in other studies (e.g. Pascual-Leone, 1995).

To strengthen the argument put forward by this thesis the effect of meditation on cognitive biases was argued for on two different foundations. First, it was argued for on a theoretical basis by considering which brain regions were consistently altered through meditation, which functions these areas fulfil and how an improvement in their function can contribute to a reduction of cognitive biases. Second, it was argued for on a more practical basis by summarising those studies which have shown that the theoretically predicted effects in the first part have been found in other studies or referring to those meditation studies that have already shown the potential of meditation to reduce a certain bias. Since both types of evidence point in the same direction without being based on each other, as for instance a practical study does not refer to plasticity effects as the reason for their findings, it is after all very likely that practising meditation can reduce the occurrence of cognitive biases.

4. A Model of Human Capital Investment

4.1. Key Features of the Job Market

In Section 3 it has been shown that the practice of meditation can reduce the occurrences of judgment errors by inducing alterations in the structure of the brain. In this Section practising meditation will therefore be regarded as an investment possibility for individuals to improve their decision making quality. Such an investment can be understood as an investment in the human capital of a worker. As such an investment is only reasonable for those individuals working in a job that features decision-making as an integral part of the job, this analysis will be limited to individuals who wish to work in certain professions. There are indeed a number of professions, in sectors such as business management, politics and medicine, in which making decisions can be regarded as the main output of an individual. In the area of medicine for instance, the decision made by physicians large determine the quality and cost of health care as Eddy (1982, p. 249) notes. Now it is not claimed that decision making constitutes the entire scope of a job, as there are certainly other tasks included, but that decision making form the part with greatest consequences and which occurs most frequently. Management executives make decisions in a high frequency, for instance which overall strategy to pursue, which price to set or which distribution channel to choose. Politicians need to decide each day which policies are optimal to address a given problem or which steps to take in a crisis situation. Physicians have to give their patience a diagnosis and decide how to treat them.

These professions not only feature decision making as an important aspect, they also face a problem with the occurrence of cognitive biases. For the field of medicine for example Eddy (1982, p. 249) points out that there is evidence that physicians make major errors when it comes to probabilistic reasoning under uncertainty and explains that this threatens the quality of medical care. That such errors are systematic and a result of the use of heuristics was noted by Tversky and Kahneman (1974) as described earlier. In a more concrete case Tversky and Kahneman (2002, pp. 29-30) show that even experienced physicians are prone to use the representative heuristic when making a diagnosis. Koehler, Brenner and Griffin (2002, pp. 697-698) add that physicians tend to neglect base rate probabilities and seem to grossly over predict mild negative events.

These type of professions not only feature decision making as an important aspect and are vulnerable to the existence of cognitive biases, but they also tend to have a hierarchical system. Businesses above a certain size usually have a board or directors and managers in lower positions. In politics there are individuals serving as ministers and others who are only a member of the parliament. In hospitals there is the assistant medical director and there are ordinary physicians. In most cases, the hierarchy involves some individuals in higher positions and the majority in lower ones. Moreover, individuals in higher positions tend to shoulder more responsibility and as a consequence earn substantially more than individuals at lower levels. Since businesses are driven by generating profits and hospitals by delivering good results, it seems in the interest of these entities to fill the jobs with the greatest responsibility with those individuals who appear to be the most able candidates for the job. In politics the situation is a bit more complex as it depends on the vote of the population which party is allowed to govern, but after an election the head of a government chooses his ministers. Given that his re-election depends on the performance of the government the office holder also has an incentive to choose the most able. In general, it can also be said that individuals prefer to reach the higher position, may it be to earn a higher wage, to have more influence or to obtain a higher status. Hence there is a competition among many people to secure what is considered to be a desirable but scarce position.

Even though it is often assumed that individuals are identical, they do actually differ in many regards. For the context of the above described professions involving decision making, an important area of heterogeneity is level of education, because individuals with a higher education are more likely to be hired for jobs featuring a higher degree of responsibility and a higher wage. In a population of employment seeking individuals some groups are hence more likely to succeed based on their existing qualifications. Since meditation is considered as an investment which can increase the human capital of an individual and an addition to the existing qualifications, it is of interest to know how the level of education of an individual and the level of competition influence the decision whether to further invest in one's human capital.

4.2. A Version of the Model with one Investment Alternative

4.2.1. The Economic Setting

A population will be considered in which individuals compete for two types of jobs in the labour market. Since all firms offering these two type of jobs are assumed to be the same the situation can be simplified to a population of n individuals competing for two type of jobs within one single firm. The individuals can be described by a single characteristic, which is denoted by H and indicates the human capital of an individual in the area of decision making. H is defined by the level of education E and the level of relevant skills S. Hence $H = (E, S)$. The individuals are heterogeneous as they enter the setting with different levels of education, which is assumed to be inalterable in model. There are three different levels of education E in this model. A fraction of m individuals has the highest education level e^{++}, a fraction l has the second highest level e^{+} and the remaining individuals have the lowest education level e. In regard of the skill level S all individuals are homogeneous and enter the model with the level s. Through making an investment in the skill an individual can reach the level s^{+} and hence increase their level of human capital. The individual has costs Ct, which are c for for investing and 0 otherwise. It is assumed that $c > 0$. The firm can observe that an investment has taken place. In both versions of the model observability of the level of human capital of an individual constitutes no problem for the firm. In this setting it is assumed that an investment in a certain skill is equivalent to the difference between two consecutive levels of education in terms of the level of human capital. However, this does not mean that the two concepts are substitutes as will be discussed in Section 5. The consequence of this assumption is that there are four different levels of human capital based on the six different combinations of education and skill level. This can be summarised as follows, beginning with the combination for the highest human capital level:

$$(e^{++}, s^{+}) > (e^{++}, s) = (e^{+}, s^{+}) > (e^{+}, s) = (e, s^{+}) > (e, s)$$

For the n individuals the firm offers two type of jobs which offer different wages W, which can be understood as the discounted aggregate income from the job over a certain period of time or the entire life-time depending on the perspective. The first job offers wage w. This job type is abundant and hence a secure option for all individuals. The second job offers wage w^{+} and $w^{+} > w$. This job type is scarce and only a fraction of the individuals will have such a job. It is assumed that all jobs paying w^{+} are filled and all those individuals not in jobs paying w^{+} will earn w . The difference between w^{+} and w can be understood as a wage premium for a better performance. The firm chooses those individuals for the better paying job who have the highest ability in term of human capital in decision making. If there are less jobs available than individuals of the highest ability, the high paying jobs will be allocated randomly to individuals of the high ability group. Members of this group have hence a certain probability to get the high paying job, while for members of the group with the lower ability this probability is zero. If there are more jobs available than there are individuals of the highest ability, all individuals of the highest ability will get the high paid job and the remaining jobs will be allocated randomly among the members of the group with the second highest ability. If there are more jobs than individuals of the highest and second highest ability, the remaining jobs will be allocated randomly among the members of the third highest ability and so on. The ranking of the abilities in term of human capital are as states above. Moreover, let j denote the number of available jobs with a wage of w^{+}. The variable j can be understood as a measure for competition, the smaller j relative to n, the higher is the competition as the scarcity of well-paid jobs increases.

The utility of an individual depends on his level of consumption C. The income of the individual constitutes the budget constraint of the individual and is given by the wage W and potential investment costs Ct. The wage depends the human capital level of all the individuals and the available high paid jobs j in relation to m, l and n. The utility function of an individual is hence given by:

$$U\,(C) = C \qquad \text{s.t.} \quad p * C \leq W - Ct$$

$$W = \; w^{+}, w; Ct = c, 0$$

If an individual can secure a high paid job depends not only on his own investment decisions, but also on those of the other individuals. Both aspects determine together the position of the individual in the human capital ranking, which represents the preferences of the firm for hiring individuals for the higher paying positions. This has two important consequences.

The first consequence is that the decision of an individual whether to invest in a skill will involve probabilities which indicate the likelihood of securing a high or low paid job. This probability is determined by decision of other individuals and the availability of high paid jobs compared to number of individuals with different education level. Such a probability is denoted as follows as p_E^S , where the lower indicator shows the education level and the upper on the skill level. Individuals are assumed to be risk neutral. An individual with the highest education level for instance will invest if the following holds:

$$p_{e^{++}}^{s^{+}} * \; w^{+} + \left(1 - \; p_{e^{++}}^{s^{+}}\right) * w - c > \; p_{e^{++}}^{s} * \; w^{+} + \left(1 - p_{e^{++}}^{s}\right) * w$$

If he invests, he has a probability of $p_{e^{++}}^{s^{+}}$ to be allocated a high paid job and a probability of $\left(1 - \; p_{e^{++}}^{s^{+}}\right)$ that he gets a less well paid jobs. This term minus the investment costs c needs to be greater than the probability $p_{e^{++}}^{s}$ that he receives a high paid job without investing plus the probability of $\left(1 - p_{e^{++}}^{s}\right)$ to receive a less well paid job to make an investment in a skill beneficial for the individual. This can be simplified to:

$$(p_{e^{++}}^{s^{+}} - p_{e^{++}}^{s}) > \frac{c}{w^{+} - w}$$

The decision problem looks similar for the individuals with another education level and hence the expression can be generalized to the following condition, which needs to hold to make an investment beneficial for the given education level of the individual:

$$(p_E^{s^{+}} - p_E^{s}) > \frac{c}{w^{+} - w}$$

This expression can also be rearranged to highlight the condition between the relative size of the investment costs and the wage premium that need to be fulfilled for an investment to be beneficial:

$$w^{+} - w > \frac{1}{p_E^{s^+} - p_E^{s}} c \qquad \text{for } (p_E^{s^+} - p_E^{s}) \neq 0$$

The second important consequence is that the individuals engage in strategic decision making and take the decisions of the other individuals into account when making their own decision. It is assumed that all individuals make the decision whether to invest independently and simultaneously so that no individual can observe the choice of other individuals before making their own choices. In order to analyse the situation of the individuals economically, the described strategic interdependence will be translated into a game and the solution concept of IESDS will be applied to investigate for which individuals it is beneficial to invest depending on their initial education level.

4.2.2. The Version of the Model with one Investment Alternative as a Game

4.2.2.1. General Assumptions

Before describing the game in greater detail a few general assumptions are necessary. The described economic setting can be translated in a static game of complete information. The following four components therefore are assumed to be common knowledge among all players of the game as this is required for a properly functioning of this specific type of game (Tadelis, 2013, p. 45): 1) all possible actions of all players, 2) all possible outcomes, 3) how each combination of actions of all the players affects which outcome will materialize and 4) the preferences of every player over outcomes. The concept of common knowledge can be defined as follows. A certain event E is common knowledge if everyone knows E, everyone knows that everyone knows E, and this reasoning is continued ad infinitum (Tadelis, 2013, p. 45). Moreover, players are assumed to be rational, which means that a player will choose his strategy $s_i \in S_i$ to maximize his payoff consistent with his beliefs, what will happen during the game. In addition, players are considered to be intelligent and therefore know and understand the four components outlined above. It is further assumed that it is common knowledge among all players of the game that players are rational and intelligent. Since players are assumed to engage in non-cooperative behaviour another requirement is that any prediction of a solution concept must be self-enforcing.

4.2.2.2 The formal Setup

Players: $N = \{1,2,3,4,5,6,7,8,9\}$

Individual strategy sets: $S_i = \{N, S\}$ for all $i \in \{1,2,3,4,5,6,7,8,9\}$

Playing strategy N does not increase the level of the skill level S, but playing this strategy also involves no costs. Playing strategy S increases the skill level S of the respective player from s to s^{+} and involves the cost c. All players choose their strategy simultaneously and independently in the beginning of the game.

To take into account the heterogeneity of the different players in regard of their education level E, the nine players will form three different groups. Moreover, since all players within the same group have the same strategies available to them and face the same payoffs their strategy choice will be the same in pure strategies, even though each player chooses his preferred strategy independently.

Groups of Players: $G_1 = \{1,2,3\}: e^{++}; G_2 = \{4,5,6\}: e^{+}; G_3 = \{7,8,9\}: e$

Group strategy sets: $S_g = \{N, S\}$ for all $g \in \{G_1, G_2, G_3\}$

Payoffs:

1. For members of G_1, let $v_i(S_i, S_{-iG_1}, S_{G_2}, S_{G_3})$ be the payoff to player i if player i chooses S_i, the other members of G_1 choose S_{G_1}, members of G_2 choose S_{G_2} and members of G_3 choose S_{G_3}.
2. For members of G_2, let $v_i(S_i, S_{G_1}, S_{-iG_2}, S_{G_3})$ be the payoff to player i if player i chooses S_i, the members of G_1 choose S_{G_1}, the other members of G_2 choose S_{G_2} and members of G_3 choose S_{G_3}.
3. For members of G_3, let $v_i(S_i, S_{G_1}, S_{G_2}, S_{-iG_3})$ be the payoff to player i if player i chooses S_i, the members of G_1 choose S_{G_1}, members of G_2 choose S_{G_2} and the other members of G_3 choose S_{G_3}.

For example $v_1(S, N, N, S)$ denotes the payoff for player 1 when player 1 chooses strategy S, player 2 and 3 choose strategy N, players 4 to 6 choose strategy N and player 7 to 9 choose strategy S. If a player deviates from the choices made by the other members of the same group it is only for the purpose of analysing the game, in the equilibrium of the game all players of the same group will choose the same strategy. The payoffs of the players in the game do not only depend on the choices of the other players, but also on the amount of high paid jobs available in round 1, indicated by j. These j jobs are allocated based on the level of human capital of the different players by applying the following steps.

Step 1: If j is equal to the number of players with the highest human capital level, all these players are given a high paid job. The allocation process ends.

If j is smaller than the number of players with the highest level of human capital in the group of all players, the j jobs are allocated randomly among all players featuring this highest level of human capital. The allocation process ends.

If j is larger than the number of players with the highest level of human capital in the group of all players, all these players are given a high paid job. The allocation process continues with step 2.

Step 2: If the remaining number of high paid jobs is equal to the number of players with the next highest human capital level, all these players are given a high paid job. The allocation process ends.

If the remaining number of high paid jobs is smaller than the number of players with the next highest level of human capital in the group of all players, these remaining jobs are allocated randomly among all players featuring this next level of human capital. The allocation process ends.

If the remaining number of high paid jobs is larger than the number of players with the next highest level of human capital in the group of all players, all these players are given a high paid job. The allocation process continues with a repetition of step 2 until all high paid jobs are allocated.

The human capital levels, indicated by the strategy choices of the different groups, are ranked as follows. The highest level is listed first and the following levels are then listed below:

$$S_{G_1} = \{S\}$$
$$S_{G_1} = \{N\}\,; S_{G_2} = \{S\}$$
$$S_{G_2} = \{N\}\,; S_{G_3} = \{S\}$$
$$S_{G_3} = \{N\}$$

Since the allocation process of the high paid jobs and the promotion involves randomness in some cases, the payoffs of the players are the expected utility of a player for a given combination of chosen strategies. In order to summarise strategy combinations with the same outcome, the following further notation element is used. $(\cdot)$ summarises both possible strategies in cases, in which the action chosen by members a particular group is irrelevant for the payoff of a player. $v_1(S, N, N, \cdot)$ for examples summarises the cases of $v_1(S, N, N, N)$ and $v_1(S, N, N, S)$.

While the payoffs of the game are different depending on the available number of high paid jobs, listing all the payoffs for the different versions of the game will bring little additional insight. Instead all relevant payoffs for the case *j*= 4 shall serve illustrate the general concept.

$v_i(S_i, S_{-iG_1}, S_{G_2}, S_{G_3})$ for all $i \in \{1,2,3\}$

$$v_i(S,\cdot,\cdot,\cdot) = w^+ - c$$
$$v_i(N,\cdot,N,\cdot) = w^+$$
$$v_i(N,S,S,\cdot) = \tfrac{1}{2}w^+ + \tfrac{1}{2}w$$
$$v_i(N,N,S,\cdot) = \tfrac{2}{3}w^+ + \tfrac{1}{3}w$$

$v_i(S_i, S_{G_1}, S_{-iG_2}, S_{G_3})$ for all $i \in \{4,5,6\}$

$$v_i(S,\cdot,N,\cdot) = w^+ - c$$
$$v_i(S,S,S,\cdot) = \tfrac{1}{3}w^+ + \tfrac{2}{3}w - c$$
$$v_i(S,N,S,\cdot) = \tfrac{2}{3}w^+ + \tfrac{1}{3}w - c$$
$$v_i(N,\cdot,S,\cdot) = w$$
$$v_i(N,\cdot,N,S) = \tfrac{1}{6}w^+ + \tfrac{5}{6}w$$
$$v_i(N,\cdot,N,N) = \tfrac{1}{3}w^+ + \tfrac{2}{3}w$$

$v_i(S_i, S_{G_1}, S_{G_2}, S_{-iG_3})$ for all $i \in \{7,8,9\}$

$$v_i(S,\cdot,S,\cdot) = w - c$$
$$v_i(S,\cdot,N,S) = \tfrac{1}{6}w^+ + \tfrac{5}{6}w - c$$
$$v_i(S,\cdot,N,N) = \tfrac{1}{4}w^+ + \tfrac{3}{4}w - c$$
$$v_i(N,\cdot,\cdot,\cdot) = w$$

The following two examples shall help to understand why certain combinations lead to the given expected payoffs for the players.

Example 1: $v_1(N, S, S, \cdot) = \frac{1}{2}w^+ + \frac{1}{2}w$

The other players of G_1 invest in S and thus reach the highest possible human capital level. Since no other player can reach the same level with the given strategy choices, the other members of G_1 secure two of the four available jobs paying wage w^+. Through investing in S players of G_2 eliminate any chances of players of G_3 to secure one of the two remaining jobs yielding w^+ as there exists no strategy choice for the latter group to reach the human capital level of the former group. At the same time members of G_2 reach the same human capital level of player 1, because player 1 chooses to not invest and hence not to bear any investment costs. Since these four players have the same level of human capital, the two remaining jobs offering w^+ will be allocated randomly among these four players. This leaves player 1 with a 50% chance of securing wage w^+ and a 50% chance of being allocated to a job with the standard wage w.

Example 2: $v_4(S, S, S, \cdot) = \frac{1}{3}w^+ + \frac{2}{3}w - c$

Since players of G_1 choose to invest in S and three of the four available jobs offering w^+ are allocated them as no other player can reach the same human capital level regardless of their strategy choice. Through investing in S members of G_2 eliminate any chances of players from G_3 to secure the last remaining job yielding w^+ as there exists no strategy choice for the latter group to reach the human capital level of the former group. As all players of G_2 choose strategy S, they all reach the same human capital level and the last remaining job with a wage of w^+ is randomly given to one of them. Therefore player 4 has a one-in-three chance of securing a wage w^+ and will receive wage w with a probability of two-thirds. Since player 4 chose strategy S he has to be bear the investment costs c in any case.

4.2.2.3. The Solution Concept and Equilibria

In order to predict the behaviour of the players in the game the solution concept of iterated elimination of strictly dominated strategies (IESDS) is applied to find the iterated-elimination equilibrium in pure strategies for the different versions of the game. This solution concepts rests on the assumption of common knowledge of rationality, which made in two steps when describing the game. First, it has been assumed that players are rational. It follows from this assumption that they will never play a strategy that is strictly dominated. Second, it has been pointed out that it is considered to be common knowledge that all players are rational. It follows from this common knowledge of rationality that all strictly dominated strategies can be eliminated as each player knows that another player will not play a dominated strategy.

While applying the process of IESDS involves a number of calculation for each version of the game, it will be refrained from supplying all these calculations as it offers, similar to before with the payoffs for the different versions, little additional insight. Instead the calculations for one version of the game can be found in the appendix-A1 for a general understanding of the application of IESDS for this game.

The payoffs of the players in this game depend on the value of the variables w^+, w and c. In order to find the equilibrium in the different versions of the game, some assumptions are necessary regarding the relationship of these variables, in particular between the wage premium $(w^+ - w)$ and the investment costs c. In this game with three players in every education level group an important condition that needs to hold for a meaningful analysis is that $(w^+ - w) > 3c$ as it ensures that players actually have an incentive to compete for the jobs offering w^+. To see this consider the following example for player from G_1 and $j = 1$:

$$v_i(S,S,N,N) > v_i(N,S,N,N)$$
$$\frac{1}{3}w^+ + \frac{2}{3}w - c > w$$
$$w^+ - w > 3c$$

If $(w^+ - w)$ would be less than $3c$ players would prefer not to compete as the investment costs are too high in comparison to the potential wage gains. The condition $(w^+ - w) > 3c$ is sufficient to find a unique equilibrium for most cases of the game. Yet, for the cases of $j = 5$ and $j = 8$ further conditions need to be specified to find the equilibrium. Table 1 summarises the equilibria in different versions of the game and shows which occurs for which relationship between the wage premium and the investment costs. The equilibria for all the versions of the game with $j < 9$ are reported below as key feature of this game is that there is competition between players, which would not be the case if $j = 9$.

	$3c < w^+ - w < 4c$	$4c < w^+ - w < 6c$	$6c < w^+ - w$
$j = 1$	(S, N, N)	(S, N, N)	(S, N, N)
$j = 2$	(S, N, N)	(S, N, N)	(S, N, N)
$j = 3$	$(\cdot,\cdot, N)$	$(\cdot,\cdot, N)$	$(\cdot,\cdot, N)$
$j = 4$	(S, S, N)	(S, S, N)	(S, S, N)
$j = 5$	(N, S, N)	$(\cdot, S, N)$	(S, S, N)
$j = 6$	$(N,\cdot,\cdot)$	$(N,\cdot,\cdot)$	$(N,\cdot,\cdot)$
$j = 7$	(N, S, S)	(N, S, S)	(N, S, S)
$j = 8$	(N, N, S)	$(N,\cdot, S)$	(N, S, S)

Table 1, Equilibria in the different versions of game 1, own creation.

In most versions of the game a unique iterated-elimination equilibrium can be found. A brief discussion will follow on those cases, for which it was not possible to narrow down the choices of all the groups of players to exactly one strategy, in order to illustrate where the prediction power of the solution concept and that of the model end.

For $j = 5$ and $6c > w^+ - w > 4c$ the decision of players of G_1 depend on what these players believe the other players of G_1 will play. If they believe the other players will choose S, their best response would be to play S as well. If they believe the other players will play N, their best response would be to play N too. None of the two strategies is therefore strictly dominated. Players of G_2 face the same situation for $j = 8$ and $6c > w^+ - w > 4c$.

For $j = 3$ players of G_3 will choose strategy N, because strategy S is not sufficient to raise their human capital to a level that is needed to compete for the available jobs, but still leads to investment costs. The choices of players from G_1 and G_2 cannot be predicted with the solution concept applied. If the players of G_2 would invest it would be beneficial for players of G_1 to also invest. However, if players of G_1 invest it is better for member of G_2 not to invest. Then again, if players of G_2 chose not to invest, it would also be the optimal choice for members of G_1 to not invest either, which in turn makes it beneficial for players of G_2 to invest. In every situation at least one player has an incentive to deviate from his current choice given what the other players choose and such a situation cannot be solved by IESDS. It also seems that the solution concept of rationalizability offers no unique solution.

For $j = 6$ the situation is similar to the one with $j = 3$. Since players of G_1 are guaranteed a well-piad job in this version, they will choose not to invest to save the investment costs. For players of G_2 and G_3 applies the same situation as previously described for G_1 and G_2 leading to a situation, in which the choices of the different players cannot be accurately predicted.

4.2.2.4. Identification of Investment Patterns

When focussing on the strategy choice of the members of the three groups in the equilibrium, rather than on the equilibrium in general, an interesting pattern emerges, as four cases of investment behaviour in the game can be distinguished. To illustrate this pattern Table 2 summarises the strategy choice of the group members for the three scenarios when 1) there is a positive number of jobs offering w^+ available, but less than the number players of the highest education level, 2) there are more jobs yielding w^+ available than the number of players of the highest educational level, but less than the combined number of players with the two highest education levels and 3) there are more jobs with wage w^+ than combined number of players of the two highest education levels, but less than the total number of players. The results from Table 1 were reduced to these three scenarios as the investment choice of the different groups of players in most cases only depends on which scenario occurs. For the rare cases in which a choice of the members of a particular group depends on further assumptions, it is stated in the description of the Table which choice is made under which conditions. In addition, the number in each box indicates which of the four different cases characterising the investment behaviour applies for the specific group in the given scenario.

	$G_3: e$	$G_2: e^+$	$G_1: e^{++}$
$0 < j < 3$	3 N	3 N	1 S
$3 < j < 6$	3 N	1 S	2 $(S; N)^a$
$6 < j < 9$	1 S	2 $(S; N)^b$	4 N

Table 2; Choices by the different groups in equilibrium in Game 1 if $(w^+ - w) > 3c$ holds. Numbers 1-4 indicate which case of investment behaviour is observed. a: $j = 4$: strategy S is chosen; j = 5: strategy S is chosen if $(w^+ - w) > 6c$; strategy N is chosen and for $3c < (w^+ - w) < 4c$; for $4c < (w^+ - w) < 6c$ it cannot be specified if strategy S or N is chosen. b: $j = 7$: strategy S is chosen; $j = 8$: strategy S is chosen if $(w^+ - w) > 6c$; strategy N is chosen and for $3c < (w^+ - w) < 4c$; for $4c < (w^+ - w) < 6c$ it cannot be specified if strategy S or N is chosen.

Case 1: Investment due to internal group competition

In each of the three scenarios there is one group whose members choose strategy S regardless of the choices of the members from other groups and regardless of the relationship between the wage premium and the investment costs, as long as $(w^+ - w) > 3c$ holds. The driving force behind this investment decision is an internal competition within the group of players with the same education level. This internal competition refers to a situation in which there are not enough jobs offering wage w^+ available for each member of the group, when assuming that each player with higher education would secure such a job. For instance players of G_2 experience such an internal competition in the scenario $3 < j < 6$, because after a hypothetical allocation of three of these jobs to members of G_1 only one or two of these jobs remain for the three players in G_2. Such a hypothetical allocation can be justified on the grounds that the decision if they wish to secure these jobs ultimately is in the hand of the group with a higher education level as an investment leads to a situation in which their human capital level cannot be reached by players with a lower education level. Let G_e denote the group of players experiencing an internal competition. The relative shortage of jobs for the players in G_e leads to a situation in which the members of G_e compete with each other to secure the remaining jobs offering wage w^+. In order to enhance the chances of succeeding in this internal competition, choosing strategy S becomes necessary for every player of G_e. Even though securing wage w^+ is not certain with the investment, the expected payoff is still higher when choosing to invest than when choosing not to invest. Instead of showing that this holds in all the different cases in the different versions of the game, the following example shall illustrate this point for a player of G_2 with $j = 4$ given that the assumption $w^+ - w > 3c$ holds:

$$v_i(S, S, S, N) > v_i(N, S, S, N)$$
$$\frac{1}{3}w^+ + \frac{2}{3}w - c > w$$
$$w^+ - w > 3c$$

The example represents a worst case scenario for the player of G_2 as both the other members of group 2 as well as the members of G_1 also choose strategy S and thus create the highest job competition possible. Members of G_3 are irrelevant in this case as they cannot reach the same human capital level if the player from G_2 chooses strategy S. The number of available jobs offering wage w^+ for his group is also at the minimum with one, when considering that three of the four jobs currently go to players from G_1. Increasing the number of available jobs from four to five would increase the expected payoff from choosing S for the player from G_2. The same effect could be observed when players from G_1 or the other players from G_2 would choose N instead of S as chances to secure a job yielding w^+ would increase for player from G_2 resulting in a higher expected payoff. Since it is already beneficial for the player from $G_2$to invest in the worst case scenario and given that his expected payoff increases should other players play N instead of S, the player in question will play S regardless of the choice of the other players. For this conclusion to hold one more case needs to be ruled out and that is that playing N could be better than investing. The highest possible expected payoff of playing N exists in the case of $3 < j < 6$ when $j = 5$, all other members of G_2 play N and players from G_3 who could now compete for the for the remaining job offering w^+ by choosing S settle for choosing N instead. Yet, even in this case choosing S is still the better choice for the player from G_2 under the given assumptions:

$$v_i(S, \cdot, N, N) > v_i(N, \cdot, N, N)$$
$$w^+ - c > \frac{2}{3}w^+ + \frac{1}{3}w$$
$$w^+ - w > 3c$$

If the player from G_2 would not choose N in this best case scenario, he will not do so either when other players from G_2 or players from G_3 will choose S instead of N and thus reduce his expected payoff from playing N. Even though the payoff from playing S might also decrease in these case it will not fall under the threshold which makes choosing S beneficial as the first example had highlighted. In all the cases when players of a certain group face the competition within the their own group, which was described above, it is the dominant strategy for them to choose S. This particular feature of the game is also a valuable starting point for applying the solution strategy of IESDS as once the choice of one group of players is known with certainty the rational choices of the remaining players are reduced considerably.

Case 2: Investment due to external group competition.

Given the assumption of common knowledge of rationality, all players in the game know that $S_{G_e} = \{S\}$ under the given assumptions. This creates a situation of external group competition for that group of players who have the next higher education level, which shall be denoted G_{e+1}. In the case that $S_{G_{e+1}} = \{N\}$, players of G_e would reach the same human capital level as players of G_{e+1}. Hence the players from G_e would compete with the players G_{e+1} to secure one of the j jobs. This situation leaves the group of higher educated players two choices. Either they also choose to invest to secure one of these j jobs with certainty or they choose not to invest and trust their chances to be allocated a job with wage w^+ nonetheless through the random allocation. In Table 2 the situation of external group competition can always be observed in the field to the right of a field where internal competition occurs.

The reaction to the existence of external competition is in the first place defined by the level of competition. If the level of competition is high, meaning only one job with wage w^+ is available for players of G_e when considering that the remaining jobs are allocated to players of G_{e+1}, then the optimal reaction to external competition is to also choose strategy S. When the level of competition is lower and two instead of one job would remain for players of G_e, the relationship between the wage premium and the investment costs define the optimal strategy choice. If $(w^+ - w) > 6c$ strategy S is the optimal choice to response to external competition. In contrast, for the case $3c < (w^+ - w) < 4c$ it yield the higher expected payoff to choose strategy N rather than S. When $4c < (w^+ - w) < 6c$ the optimal decision depends on the belief of a player what the other players in his group will do. If he believes they will play S, he will also choose S, if he believes they will choose N, he will choose N as well. In general, it can therefore be said that players facing external competition will choose strategy S, if the competition level is high or the investment costs is sufficiently low compared to the wage premium.

Case 3: No investment due to a lack of perspective
The common knowledge that $S_{G_e} = \{S\}$ also has consequences for the group of players with the next lower education level compared to G_e, which shall be represented by G_{e-1}. For G_{e-1} it is optimal to choose strategy N, because choosing strategy S will only lead to additional costs without any chance to secure a job offering wage w^+. This conclusion can be drawn when considering the available number of jobs offering wage w^+. Since G_e already experiences internal competition, it follows that there are none of the jobs available for players of G_{e-1} when assuming that all players with a higher education would secure such a job. The only chance to secure one of the j jobs for players of G_{e-1} occurs when $S_{G_e} = \{N\}$ as in this case players of G_{e_1} could reach the same human capital level as G_e when choosing strategy S. However, due to the internal competition the actual case is $S_{G_e} = \{S\}$. Hence, strategy S is strictly dominated by strategy N for G_{e-1}. In addition, if a group of players has a level of education that is two levels lower than the one of players from G_e, which can be summarised as G_{e-2}, than these players of G_{e-2} have no chance to secure on of the j jobs regardless of which strategy any other player chooses. Hence for players of G_{e-2} choosing strategy S is also strictly dominated by choosing strategy N.

Case 4: No investment due to a lack of competition
At the same time it is possible that a group of players has an education level two levels higher than that of G_e, which can be represented by G_{e-2}. In such a case strategy S is strictly dominated by strategy N for player of G_{e-2}, because a job offering wage w^+ is already guaranteed and choosing to invest would only lead to addition costs but no benefit.

4.2.2.5. Generalization of the Insights from the Game

With the insight provided by the game regarding the driving forces behind an individual's decision, the conditions for a particular choice can now be generalized for the version of the model with one investment alternative. Let G_1 again denote those individuals with education level e^{++}, G_2 those with

e^+ and G_3 the individuals with education level e. As in the game it is important to first distinguish three scenarios, which decides which group of players experience internal competition and therefore influence the strategy choices of the other players. In general it is assumed that $0 < j < n$. In scenario 1: there are less well-paid jobs than members of G_1, which can be summarised as $j < m$. In scenario 2 there are more jobs than members of G_1 but less than members of G_1 and G_2 combined, in short $m < j < (m + l)$. In scenario 3 there are more jobs available than the combined number of members of G_1 and G_2, in short $(m + l) < j$. The cases of $j = m$ and $j = (m + l)$ are ignored as they are become increasingly rare with a growing number of individuals and because the game showed that the power to predict is severely limited in these cases. In scenario 1 members of G_1 face internal competition, in scenario 2 this is the case for individuals from G_2 and in scenario 3 for members of G_3. The first step in each scenario step is to find out under which conditions the members of the group experiencing internal competition choose to invest. As was pointed during the analysis of the game, there are two questions which are relevant in this context. First, when is it beneficial to invest in the worst case scenario, which refers to the case when all other individuals with the same level of education or higher would also invest? Second, when is it beneficial to invest in the case that is the best case scenario for not investing, which refers to a situation in which no other individual with the same or a lower education level invests? This question can be answered for all three scenarios. The second step in each scenario is then to conclude what the other groups will choose and for the group experiencing external competition to again calculate when it is beneficial to invest. In the following only the conditions will be reported, but the calculations for each scenario are given in the appendix A2.

		Equilibrium	$G_3: e$	$G_2: e^+$	$G_3: e^{++}$
Scenario 1	$j < m$	(S, N, N)			$w^+ - w > \frac{m}{j} c$ $w^+ - w > \frac{m}{m-j} c$
Scenario 2	$m < j < (m + l)$	(S, S, N)		$w^+ - w > \frac{l}{j-m} c$	$w^+ - w > \frac{l+m}{l+m-j} c$
Scenario 3	$m < j < (m + l)$	(N, S, S)	$w^+ - w > \frac{n-m-l}{j-m-l} c$	$w^+ - w > \frac{n+1-m-l}{n-j} c$	

Table 3, equilibrium conditions for the model with one investment alternative, own creation

By analysing the necessary conditions that members of given groups will choose to invest, more insight can be gained how variables in the model influence the investment decision. Generally, it is easy to see that an increase in the wage premium will ceteribus paribus increase the likelihood that individuals invest. The same effect can be observed for a reduction in the investment costs. In scenario 1 the two terms of interest are $\frac{m}{j}$ and $\frac{m}{m-j}$. If their value is reduced, the likelihood that individuals of G_1 will invest increases. It is difficult to make a general statement regarding the influence of m and j, because for $\frac{m}{j}$ a reduction in m or a j would increase the likelihood to invest. For $\frac{m}{m-j}$, however, a decrease of j would lead to the same effect. At the same time this is true for an increase in m regarding the term. For the other two scenarios the number of available jobs has a similar ambiguous effect.

4.2.3. Discussion of the Insights of the Model

The heterogeneity in the education level of the individuals establishes a hierarchy before any investment choice is made by lifting the individuals on different human capital levels. If there was no investment opportunity the available jobs with wage w^+ would therefore first go to the most educated individuals and when some remain of the j jobs remain they would go to the individuals with the next highest education level and so on. The heterogeneity of the players is the reason why the internal competition, which was described in the game, can be observed, as in most cases there are not enough jobs available jobs offering wage w^+ for all members of a particular group. The number of available jobs only decides which of the three groups will experience the internal competition.

With the exception of those cases, where from the onset individuals are either not qualified enough to compete for any jobs yielding w^+ or are endowed with a level of education that guaranteed one of these jobs given the number of available jobs offering wage w^+, the group of individuals experiencing the internal competition drive the behaviour of all other individuals. While these individuals are forced to invest to maximize their expected payoff, they also force in most cases the individuals with the next higher education level to also make the investment in the skill. It resembles to some degree a rat race. Every individual chooses to make an extra effort only to end up in the end where he has been in the beginning relative to others, with the exception of a few lucky individuals who could improve their standing. At the same time the choices of the individuals facing internal competition let the individuals with the next lower education level refrain from making an investment in their human capital. The four identified investment behaviours combined with the understanding how the number of available jobs with a higher wage defines which group will use which behaviour constitute the main insight from this version of the model with one investment.

4.3. A version of the Model with two Investment Alternatives

4.3.1. The Motivation

Despite offering some insight about the investment behaviour the previously described model has two shortcomings. First, the skill in which an individual can invest could be any skill that is relevant for the given job. Such a setting does not yield particular insight about investment into meditation. Second, the setting is not very realistic as individuals tend to have a choice between different investment alternatives and can choose to invest in the skill they prefer, but in the first model that was described there was no such alternative as only one type of investment was available. The second version of the model is meant to address these shortcomings. To take into account the different options usually available to people, the individuals in the model have two different investment opportunities. While the first is an investment into a given skill as before, the second investment opportunity is supposed to resemble an investment in meditation as this thesis is particularly interested in this investment. Since people tend to have limited resources in terms of time and money they can usually only pursue one investment at a time. It appears like a reasonable view of the world that firms, when first allocating high paid positions, are more interested in some specific skills than in others. For instance a firm might be more interested in an applicant with certain programming skills than in one who practises meditation when both have a similar education level. At the same time it seems that when moving up the hierarchy in a firm the entry skills such as programming become less relevant as the employee is more involved in deciding important matters while newer employees are busy with doing the programming for him. In the long run meditation as the more general skill improving decision making abilities becomes therefore more valuable in the long run for the firm. This conclusion also seems reasonable when considering that long-term practice of meditation will likely have a larger effect in terms of brain plasticity than short-term practice. These different characteristics of the two investment regarding their respective short and long term effect will therefore be incorporated in the following model setting.

4.3.2. The Model with two Investments Alternatives

The considered population only changes in one aspect compared to the previous model and that is that the skill level S in $H = (E, S)$ now includes the level of an ordinary skill s and the meditation skill m. Through an investment in the ordinary skill an individual reaches s^+, while an investment in meditation brings the individual to the level m^+. An individual can only make one investment and therefore faces the choice to invest in the skill, in meditation or not at all. Ignoring the different education levels for the moment an individual can have the three following human capital levels $H = (E, s^+, m); (E, s, m^+); (E, s, m)$. The cost for the investment is equal c for both the investment into the skill and for the investment in meditation. An investment can only be made in the very beginning and decisions are made simultaneously and independently. Again it is assumed that firms can observe the human capital level of an individual without experiencing any problem. Even though it is not relevant for the model how exactly this works for the case of meditation induced plasticity, a solution could be found for this problem by leaving it to the market to supply some sort of certificate for meditation practice.[2]

Compared to the previous setting of the labour market there are two important differences. First, while individuals will begin as before with competing for scarce jobs offering wage w^+ , a new second round competition is introduced in which all individuals, who managed to secure one of the j well paid jobs in the first round, compete again for one of the even scarcer p positions offering an additional payment b on top of w^+. All those individuals who do not get one of the p positions receive no further payment. Second, since the human capital level is now defined through three elements it has to reconsidered which combination is preferred by the firm at which stage. As outlined before specific skills appear to be more valuable to the firm in the beginning and therefore an investment in the ordinary skill s is preferred to an investment into meditation in the first round. In addition an investment in s brings an individual to the same human capital level as an individual with a higher education level making no investments. Given that any investment is preferred to no investment for the same education level, the following describe the preferences of the firm in terms of the human capital level for the first round when individuals compete for w^+ and w:

$$(e^{++}, s^+, m) > (e^{++}, s, m^+) > (e^{++}, s, m) = (e^+, s^+, m) > (e^+, s, m^+) > (e^+, s, m) = (e, s^+, m) > (e, s, m^+) > (e, s, m)$$

In the second round when all individuals who secured on of the jobs paying w^+ compete again for the p positions bringing a bonus, the investment in meditation will be regarded more valuable to the firm

[2] It appears plausible that firms cannot observe an alteration in the brain of job applicants nor evaluate their former decision-making record regarding wrong decision due to cognitive biases at reasonable cost, because of the vast amount of information involved in taking a single decision. This creates a problem as both those individuals who meditate and those who do not would claim to engage in meditation to signal a higher human capital. This problem could be addressed by obtaining a certificate, which proves that an individual has visited a meditation centre long enough or participated in a meditation course with a certain length that it is fairly certain that the desired alterations have been achieved. It is assumed that the market will provide the possibility to acquire such certificates in a similar fashion as it takes care to provide education diplomas or certificates of other skills. It is also assumed that if individuals choose to meditate they obtain the certificate, they do not meditate to receive other benefits without also claiming the certificate. Moreover, if individuals participate in a meditation programme it is assumed that they actually engage in meditation and do not sit around to obtain the certificate.

than an investment in the specific skill. The growing importance is expressed by transforming m^+ into m^{++} and this skill is more important on the higher level. The preferences of the firm in terms of human capital level are in the second round as follows:

$$(e^{++},s,m^{++}) > (e^{++},s^+,m) = (e^+,s,m^{++}) > (e^{++},s,m) = (e^+,s^+,m) = (e,s,m^{++}) > (e^+,s,m) = (e,s^+,m) = (e,s,m)$$

The utility of an individual depends on his level of consumption C. The income of the individual constitutes the budget constraint of the individual and is given by the wage W and potential investment costs Ct. The wage depends on the human capital of the individual and others, how many high paid jobs are available in the first and second round, how large the shares of the groups with a different education level are and the overall size of the population. The utility function is given by:

$$U(C) = C \quad s.t. \quad p * C \leq W - Ct$$

$$W = w^+ + b, w^+, w; Ct = c, 0$$

Again individuals are assumed to be risk neutral and in the general case it is beneficial for an individual to invest if the following equation holds:

$$p_E^{S^+} * (w^+ + p^p * b) + \left(1 - p_E^{S^+}\right) * w - c > p_E^S * w^+ + (1 - p_E^S) * w$$

$$w^+ - w > \frac{1}{p_E^{S^+} - p_E^S} c - \frac{1}{p_E^{S^+} - p_E^S} (p_E^{S^+} * p^p * b) \qquad \text{for } (p_E^{S^+} - p_E^S) \neq 0$$

Compared to the previous version of the model the condition that needs to be satisfied to invest differs as a new term is introduced, which describes the bonus payment that can be earned. All things being equal, this introduction of a bonus payment makes investments more likely than before. Again the strategic interdependence and the optimal decision of different types of individuals will be analysed in a game setting.

4.3.3. The Game and the Solution Strategy

The same general assumptions that were made in the previous game are also made in this game.

4.3.3.1 The formal Setup

Players: $N = \{1,2,3,4,5,6,7,8,9\}$

Individual strategy sets: $S_i = \{M, N, S\}$ for all $i \in \{1,2,3,4,5,6,7,8,9\}$

Playing strategy M increases the level meditation level M of the respective player from m to m^+ before round 1 and the meditation level is further increased to m^{++} before round 2. There is no effect on the skill level S when playing strategy M, which involves the cost c. Playing strategy N increases neither the level of the skill level S nor the meditation level M in any round, but playing this strategy also involves no costs. Playing strategy S increases the skill level S of the respective player from s to s^+ before round 1 and the skill level remains at s^+ in round 2. There is no effect on meditation level M when playing strategy S, which involves the cost c. All players choose their strategy simultaneously and independently in the beginning of the game and there is no opportunity for a player to make another investment choice later or to postpone the investment decision.

To take into account the heterogeneity of the different players in regard of their education level E, the nine players will form three different groups. Moreover, since all players within the same group have the same strategies available to them and face the same payoffs their strategy choice will be the same in pure strategies, even though each player chooses his preferred strategy independently.

Groups of Players: $G_1 = \{1,2,3\}: e^{++}; G_2 = \{4,5,6\}: e^{+}; G_3 = \{7,8,9\}: e$

Group strategy sets: $S_g = \{M, N, S\}$ for all $g \in \{G_1, G_2, G_3\}$

Payoffs:

1. For members of G_1, let $v_i(S_i, S_{-iG_1}, S_{G_2}, S_{G_3})$ be the payoff to player i if player i chooses S_i, the other members of G_1 choose S_{G_1}, members of G_2 choose S_{G_2} and members of G_3 choose S_{G_3}.
2. For members of G_2, let $v_i(S_i, S_{G_1}, S_{-iG_2}, S_{G_3})$ be the payoff to player i if player i chooses S_i, the members of G_1 choose S_{G_1}, the other members of G_2 choose S_{G_2} and members of G_3 choose S_{G_3}.
3. For members of G_3, let $v_i(S_i, S_{G_1}, S_{G_2}, S_{-iG_3})$ be the payoff to player i if player i chooses S_i, the members of G_1 choose S_{G_1}, members of G_2 choose S_{G_2} and the other members of G_3 choose S_{G_3}.

For example $v_1(S, N, M, S)$ denotes the payoff for player 1 when player 1 chooses strategy S, player 2 and 3 choose strategy N, players 4 to 6 choose strategy M and player 7 to 9 choose strategy S.

If a player deviates from the choices made by the other members of the same group it is only for the purpose of analysing the game, in the equilibrium of the game all players of the same group will choose the same strategy.

The payoffs of the players in the game do not only depend on the choices of the other players, but also on the variation regarding on the amount of high paid jobs available in round 1, indicated by j, and the amount of promotions available in round 2, indicated by p. These j jobs are allocated based on the level of human capital of the different players by applying the same steps as presented for game 1. The same allocation procedure applies to the allocation of the p promotions. However, only those players who secured one of the j jobs in round 1 can compete in round 2.

The human capital levels, indicated by the strategy choices of the different groups, are ranked as follows in the two rounds. The highest level is listed first and the following levels are then listed below:

First Round	Second Round
$S_{G_1} = \{S\}$	$S_{G_1} = \{M\}$
$S_{G_1} = \{M\}$	$S_{G_1} = \{S\}\,;\ S_{G_2} = \{M\}$
$S_{G_1} = \{N\}\,; S_{G_2} = \{S\}$	$S_{G_1} = \{N\}\,; S_{G_2} = \{S\}\,; S_{G_3} = \{M\}$
$S_{G_2} = \{M\}$	$S_{G_2} = \{N\}\,; S_{G_3} = \{S\}$
$S_{G_2} = \{N\}\,; S_{G_3} = \{S\}$	$S_{G_3} = \{N\}$
$S_{G_3} = \{M\}$	
$S_{G_3} = \{N\}$	

Since the allocation process of the high paid jobs and the promotion involves randomness in some cases, the payoffs of the players are the expected utility of a player for a given combination of chosen strategies. In order to summarise strategy combinations with the same outcome, two further notation elements are used. First, $(\cdot)$ summarises all three possible strategies in cases, in which the action chosen by members a particular group is irrelevant for the payoff of a player. $v_1(S, N, M, \cdot)$ for examples summarises the cases of $v_1(S, N, M, M), v_1(S, N, M, N)$ and $v_1(S, N, M, S)$. Secondly, $\overline{N}$ summarises the two strategies that are not N in cases, in which it is irrelevant for the payoff of a player if a members of a particular group chose strategy S or M. The same concept is applied for $\bar{S}$ and $\bar{M}$. Hence $v_1(S, N, M, \bar{N})$ summarises the cases $v_1(S, N, M, S)$ and $v_1(S, N, M, M)$.

While the payoffs of the game are different for each combination of j and p, listing all the payoffs for the different versions of the game will bring little additional insight. Instead all relevant payoffs for the case with j= 5 and p = 2 shall serve illustrate the general concept.

$v_i(S_i, S_{-iG_1}, S_{G_2}, S_{G_3})$ for all $i \in \{1,2,3\}$

$v_i(M, M, \cdot, \cdot) = w^+ + \frac{2}{3}b - c$

$v_i(M, \bar{M}, \cdot, \cdot) = w^+ + b - c$

$v_i(S, M, \cdot, \cdot) = w^+ - c$

$v_i(S, S, M, \cdot) = w^+ + \frac{2}{5}b - c$

$v_i(S, S, \bar{M}, \cdot) = w^+ + \frac{2}{3}b - c$

$v_i(S, N, M, \cdot) = w^+ + \frac{2}{3}b - c$

$v_i(S, N, \bar{M}, \cdot) = w^+ + b - c$

$v_i(N, \bar{N}, S, \cdot) = \frac{3}{4}w^+ + \frac{1}{4}w$

$v_i(N, \bar{N}, \bar{S}, \cdot) = w^+$

$v_i(N, N, M, \cdot) = w^+$

$v_i(N, N, S, \cdot) = \frac{5}{6}w^+ + \frac{1}{6}w + \frac{1}{3}b$

$v_i(N, N, N, \cdot) = w^+ + \frac{2}{3}b$

$v_i(S_i, S_{G_1}, S_{-iG_2}, S_{G_3})$ for all $i \in \{4,5,6\}$

$v_i(M, \cdot, S, \cdot) = w - c$

$v_i(M, M, M, \cdot) = \frac{2}{3}w^+ + \frac{1}{3}w - c$

$v_i(M, M, N, \cdot) = w^+ - c$

$v_i(M, S, M, \cdot) = \frac{2}{3}w^+ + \frac{1}{3}w + \frac{4}{15}b - c$

$v_i(M, S, N, \cdot) = w^+ + \frac{1}{2}b - c$

$v_i(M, N, M, \cdot) = \frac{2}{3}w^+ + \frac{1}{3}w + \frac{2}{3}b - c$

$v_i(M, N, N, \cdot) = w^+ + b - c$

$v_i(S, \bar{N}, S, \cdot) = \frac{2}{3}w^+ + \frac{1}{3}w - c$

$v_i(S, \bar{N}, \bar{S}, \cdot) = w^+ - c$

$v_i(S, N, M, \cdot) = w^+ + \frac{1}{4}b - c$

$v_i(S, N, S, \cdot) = \frac{5}{6}w^+ + \frac{1}{6}w + \frac{1}{3}b - c$

$v_i(S, N, N, \cdot) = w^+ + \frac{1}{2}b - c$

$v_i(N, \cdot, \bar{N}, \cdot) = w$

$v_i(N, \cdot, N, \bar{S},) = \frac{2}{3}w^+ + \frac{1}{3}w$

$v_i(N, \cdot, N, S,) = \frac{1}{3}w^+ + \frac{2}{3}w$

$v_i(S_i, S_{G_1}, S_{G_2}, S_{-iG_3})$ for all $i \in \{7,8,9\}$

$v_i(M, \cdot, N, \cdot) = w - c$

$v_i(S, \cdot, N, S) = \frac{1}{2}w^+ + \frac{1}{2}w - c$

$v_i(S, \cdot, N, \bar{S}) = \frac{1}{2}w^+ + \frac{1}{2} - c$

$v_i(\bar{N}, \cdot, \bar{N}, \cdot) = w - c$

$v_i(N, \cdot, \cdot, \cdot) = w$

When attempting to understand the payoff for a given strategy combination it is crucial to keep in mind that the payoff calculation involves two steps. In a first step, it is necessary to understand the chances of a player to receive one of the j high paid jobs in round 1 given the chosen strategies of all players. In the second step, the chances of all those players, who have advanced to round 2 through securing one of the j jobs in round 1, of getting one of the p promotions have to be evaluated in regard of the chosen strategies by the different players. The following two examples shall illustrate this process and enhance the understanding of the payoff calculation.

1. Example: $v_1(N, N, M, \cdot) = w^+$

Since players of G_2 chose strategy M they cannot reach the human capital level of player 1 in round 1 and neither can members of G_3 regardless of their choice. In round 1 player 1 has together with the other players G_1 the highest level of human capital and is therefore allocated one of the j jobs. Since player 1 chose N he has no investment costs. Two of the remaining well-paid jobs are allocated to the other members of G_1 as they have the highest human capital level together with player 1. Players of G_2 compete for the remaining two jobs offering w^+, because by playing strategy M they made it impossible for players of G_3 to reach the same human capital level in round 1. In round 2 the two players from G_2, who were allocated one of the j jobs in round 1, have the highest human capital due to their investment choice M. The two available promotions therefore go to these two players and player 1 has no chance to receive the bonus payment.

2. Example: $v_4(M, S, M, \cdot) = \frac{2}{3}w^+ + \frac{1}{3}w + \frac{4}{15}b - c$

In round 1 players of G_1 secure one of the j jobs each, because through investing in S these players have the highest possible human capital level in that round and no other player can reach level regardless of their strategy choice. The remaining six players therefore compete for the remaining two jobs offering w^+. By choosing strategy M players of G_2 made it impossible for members of G_3 to reach their human capital regardless of the chosen strategy. At the same time players of G_2 all reach the same human capital level as they all chose the same strategy. As a consequence the remaining two jobs yielding w^+ are allocated randomly among the three players in G_2. Hence, each of these three players has a two-third chance of being allocated a job paying w^+ and a one-third chance of being unlucky and receiving a job paying only w. Since player 4 chose strategy M has the costs c in any case. Player 4 has a two-third chance to advance in round 2 to compete for the two promotions paying an extra b. If he advances to round 2 he has a two-fifth chance to secure a promotion. Since it is uncertain if he is selected though, the two probabilities need to be multiplied to arrive at the final probability of securing a promotion. In this case that is $\frac{2}{3} * \frac{2}{5} = \frac{4}{15}$.

4.3.3.2. The Solution Concept and Equilibrium

The same solution concept of IESDS that was explained and applied in the previous game is also used for this game. Similarly, one example of its application will again be given in the appendix-A3 to provide a general understanding of the concept in the context of this game, instead of providing all the calculations for the different versions of the game.

Some restriction regarding j and p need to be made as not all of the possible combinations of these two variables represent the described game or fit the purpose of analysis. As in the previous game only versions of the game with $j < 9$ will be taken into account as competition between players is an essential part of the game design. With $j = 9$ there would be no competition in the first round of the job allocation and the structure of the game would be a different one. Following the same logic another restriction is that only versions satisfying $1 \leq p < j$ will be reported. If $p = j$ was possible, there would be no competition no competition in the second round of the job allocation and all players who secured one of the j jobs in the first round would automatically receive the bonus b. If $p = 0$ there would again be no competition in the second round of the job allocation. Since the second restriction made rules out $j = 1$ it should be pointed out for the curious reader that the strategies played in the equilibrium are the same as in the case of $j = 2$.

In order to find the strategies that are played in an equilibrium some assumptions are necessary regarding the relation between the variables w^+, w, c and b. Due to the introduction of the bonus payment b, which is paid after securing one of the p promotions, there needs to be an assumption made regarding the relationships between the bonus payment and the wage premium and between the bonus payment and the investment costs, in addition to the assumption that has already been introduced in the previous game between the wage premium and the investment costs. In the different version of the game featuring a particular combination of j and p the minimum requirement of these three assumptions differs and in some versions one of them is not needed at all. Since the strategies that are played in the equilibrium constitute the more interesting aspects compared to the different assumptions made in every single version, the results will be presented as follows to not confuse the reader with too many details. In Table 4 the strategy choices of the groups with the different education level will be reported for the different combinations of j and p. In the following the most extreme version for the three assumptions will be outlined and these assumptions ensure that all the reported equilibria exist. In the Appendix-A4 the same results will be presented together with the assumptions that are necessary for each case. In most cases the crucial values needed in the different assumptions will be lower than the most extreme cases.

The same assumption as in the previous game is made for the same reason in this game for the relation between the wage premium and the investment costs. It is hence assumed that $(w^{+} - w) > 3c$ holds.. At the same time the assumption that $b > 3c$ is needed to be fulfilled to ensure it is worth competing for the promotion. The last assumption that needs to be made is that $(w^{+} - w) > \frac{7}{4}b$, which is needed to ensure that the solution concept of IESDS produces meaningful results. It has to be pointed out though, that the last assumption is only needed when j and p are close to being equal.

	$p = 7$	$p = 6$	$p = 5$	$p = 4$	$p = 3$	$p = 2$	$p = 1$
$j = 2$							(S,N,N)
$j = 3$						(M,N,N)	(M,N,N)
$j = 4$					$(\bar{N},S,N)$	(M,S,N)	(M,S,N)
$j = 5$				$(\bar{N},S,N)$	$(\bar{N},S,N)$	(M,S,N)	(M,S,N)
$j = 6$			(M,M,N)	(M,M,N)	$(\cdot,\cdot,\cdot)$	$(M,\cdot,\cdot)$	$(M,\cdot,\cdot)$
$j = 7$		$(N,\bar{N},S)$	(M,M,S)	(M,M,S)	$(M,\bar{N},S)$	$(M,\bar{N},S)$	$(M,\bar{N},S)$
$j = 8$	$(N,\bar{N},S)$	$(N,\bar{N},S)$	(M,M,S)	(M,M,S)	$(\cdot,\cdot,S)$	$(M,\cdot,S)$	$(M,\cdot,S)$

Table 4, Equilibria in the different versions of game 2, own creation

In many versions of the game a unique iterated-elimination equilibrium can be found. A brief discussion will follow on those cases, where it was not possible to narrow down the choices of all the groups of players to exactly one strategy, in order to illustrate where the prediction power of the solution concept and that of the model end.

For $j = 7$ and $p < 4$ it is indicated that members of G_2 will play $\bar{N}$. The reasoning behind is as follows. Following the logic of the previous game, players from G_3 choose strategy S as they face internal competition. For players of G_2 it is optimal to react to this external competition by also choosing a strategy that involves investing. However, both, choosing strategy M and choosing strategy S, are sufficient to this end. If players of G_1 play strategy M both strategies yield the same expected payoff and hence none is strictly dominated. However, it should be noted that S is weakly dominated by M.

For the cases in which $p > 5$, the choice of players in G_2 is also indicated by $\overline{N}$, the reasoning differs to the previous case though. In order to defend himself from the external competition created by G_3 a player from G_2 needs to choose a strategy involving an investment. However, players of G_3 are limited in their choice as they need to choose strategy S in order to secure one of the j jobs in the first round. Even though strategy M promises better chances in the second round when promotions are allocated, this strategy is dominated by strategy S under the given assumptions. If the player from G_3 chooses strategy M, while the other players of G_3 choose strategy S, he would not be allocated one of the j jobs in the first round, because his human capital level would be lower than the one of his competitors. As a consequence he would not even be able to compete in the second round. Even when all players from G_3 chose strategy M there would be an individual incentive to deviate to choosing S under the given assumptions. Since the players of G_3 are therefore forced to choose S, it makes no difference for a player from G_2 whether to choose strategy S or M, both ensure the highest possible payoff minus the investment costs.

For the cases in which $j = 5, p = 3; 4$ and $j = 4, p = 3$ players of G_1 are indicated to play $\overline{N}$ in the equilibrium and the same explanation as just given in the previous case simply needs to be applied to different groups. This time players of G_1 need to defend themselves from players of G_2 to secure one of the j jobs and one of the p promotions. The internal competition in G_2 forces the players in the group to play strategy S and hence strategy S as well as strategy M are sufficient for the purposes of players from G_1 and lead to the same expected payoff.

For $j = 8$ and $p < 3$ it is indicated that G_2 could choose any strategy under the given assumptions. While players of G_1 experience internal competition when attempting to secure a promotion and hence are forced to play strategy M, players of G_3 face internal competition when trying to secure one of the available j jobs and as a consequence need to select strategy S. Since it is impossible to secure a promotion for players of G_2 given the choices of G_1, no strategy can be excluded based on optimal behaviour regarding the second round. Under the standard assumption of $w^+ - w > 3c$, that suffices in all other versions of the game, it is not clear what the optimal response to the external competition from G_3 is for players from G_2. However, with a stricter assumption than $w^+ - w > 3c$, the choice of players in G_2 can be further narrowed down. The case resembles the case of $j = 8$ from the first game and hence for $3c < w^+ - w < 4c$ members of G_2 will choose strategy N and for $w^+ - w > 6c$ they will choose $\overline{N}$ as both strategies suffice to defend the player against the external competition. When $4c < w^+ - w < 6c$ the choice depends again on what players of G_2 believe the other players of G_2 will choose and cannot be narrowed down further with the applied solution concept.

The version with $j = 8$ and $p = 3$ features the same problem that the behaviour of G_2 cannot be predicted with the standard assumption $w^+ - w > 3c$. In addition, it is not clear that players of G_1 will choose a strategy involving an investment as in some choosing strategy N generates a higher expected payoff, for instance when players of G_2 do not invest. The internal competition regarding the promotions is lacking as a driving force here. When assuming that $w^+ - w > 6c$ the external competition experienced by G_2 can function as a ground for further predictions. G_2 will choose $\overline{N}$ to secure wage w^+ and for G_1 strategy M is weakly dominant. For the other possible assumptions no clear prediction of behaviour can be given as the uncertainty regarding the behaviour of G_2 and G_1 deviating from the choice of the rest of the group is often beneficial. Such a situation cannot be solved by applying the solution concept of IESDS.

For $j = 6$ and $p < 3$ the behaviour of G_1 can be predicted based on the internal competition for the available p promotions. Yet, for the other two groups it cannot be stated which strategies will be chosen based on the solution concept of IESDS. Since there is no internal competition in the first round none of the two groups has a dominant strategy. Moreover, players tend to have an incentive to deviate from the choices of the rest of the group, which cannot be the case in a stable equilibrium. Using stricter assumptions can also not solve this problem. In the end, a player's choice depends on what a player believes regarding the choices of the other players and it seems that none of these believes can be ruled out, even when applying other solution concepts.

For $j = 6$ and $p = 3$ the situation is even worse as there is no internal competition neither in the first nor in the second round. As a consequence no player has a dominant strategy and this version can also not be solved by applying IESDS. Depending on what the players believe other players will do they will choose their strategy, but this version provides no information which strategies could be preferred to others, apart from the fact that for securing one of the j jobs in the first round strategy S weakly dominates strategy M and vice versa when it comes to securing on of the p promotions in the second round.

4.3.3.3. Identification of Investment Patterns

Similar to the first game, six different cases of investment behaviour can be distinguished when focusing on the strategy choice of the members of the three groups in the equilibrium. These choices are summarised in Table 5 in the following dimensions. On the one hand the different cases are distinguished in the same three scenarios already used in the previous game for the amount of available jobs offering wage w^+ in the first round. On the other hand these scenarios are mirrored for the amount of available promotions in the second round. The same assumptions are assumed to hold, which were already assumed for Table 4. In addition, the number in each box indicates which of the six different cases characterising the investment behaviour applies for the specific group in the given scenario.

	G_3: e			G_2: e^+			G_1: e^{++}		
	$8 > p > 6$	$6 > p > 3$	$3 > p > 0$	$8 > p > 6$	$6 > p > 3$	$3 > p > 0$	$8 > p > 6$	$6 > p > 3$	$3 > p > 0$
$1 < j < 3$			N 5			N 5			S 1
$3 < j < 6$		N 5	N 5		S 1	S 1		$\bar{N}$ 3	M 2
$6 < j < 9$	S 1	S 1	S 1	$\bar{N}$ 3	M 2	$\bar{N}^a$ 3	N 6	M 4	M 2

Table 5, Choices by the different groups in equilibrium in game 2 if $(w^+ - w) > 3c$ holds. Numbers 1-6: indicate which case of investment behaviour is observed. a: For $j = 8$ and $3c < w^+ - w < 4c$ players of G_2 will actually choose strategy N and for $j = 8$ and $4c < w^+ - w < 6c$ strategy N is also a possible choice of members of G_2.

The concept of internal competition that was introduced in the game with one investment choice is also relevant in this game. This time the concept is relevant in two cases as there are two rounds of competition. The group of players experiencing internal competition when competing for the j jobs in the first round are denoted by G_{1e} and their situation is described in case 1. Case 2 describes the situation of the group of successful players from the first round who experience internal competition when attempting to secure one of the p promotions. Let G_{2e} denote this group. Players can belong to

G_{1e} and at the same time to G_{2e}. As seen in the game with one investment alternative, the internal competition within a group can force the group of players with the next higher education level to also choose a strategy involving an investment. The same phenomenon can be observed in this game in both the first and the second round competition. The group of players experiencing this external competition are denoted by G_{1e+1} and G_{2e+1} respectively. In some versions of the game a situation of external competition in the first round also involves an internal competition for promotions. These cases of internal competition are described before the cases of external competition in the first round are described in case 3 and those the second round in case 4. Similar to the game with one investment, there are also versions of the game in which players choose not to invest due to a lack of perspective, which is outlined in case 5, and due to a lack of competition which is outlined in case 6.

Case 1: Internal Competition in the first round

Similar to the situation described in the game with one investment alternative, choosing strategy S is the dominant strategy for players of the group G_{1e}. The same logic as presented in the first game applies to why the strategy N is strictly dominated. Since the players in the game have another option available in strategy M, a short explanation is necessary why this strategy is also strictly dominated under the given assumptions. In the first round, when players compete for the j jobs offering wage w^+, strategy S is stronger than strategy M as the former enables the respective player to reach a higher human capital level. If a player who chooses strategy M competes in the first round with a player who chooses S, the latter player will therefore secure the job with the higher wage due to his higher human capital level. Choosing strategy M while everyone else chooses strategy S ultimately leads to zero chances of securing the higher wage while still incurring the investment costs. At the same time it turns out to be beneficial to choose S when everyone chooses M under the given assumptions, despite the potential benefits in the competition for the promotions.

While strategy M would help the player more in the second round, he would only be capable to compete if he secured one of the j jobs in the first round and he will only manage do this if he chooses strategy S since collusion among players is ruled out by the assumptions made. If a player is part of G_{1e} it follows not only that he will choose strategy S, but also that by doing so he sacrifices the possibility to do better in the second competition for the p promotions. In other words, being trapped in the short-term competition ensures that a player cannot reach his highest possible human capital level in the long-term.

Case 2: Internal Competition in second round, but not in the first round

Following the same logic as with the internal competition in the first round, members of G_{2e} are forced to choose a strategy involving an investment, because competing for the available promotions yields a higher expected payoff than choosing not to invest under the given assumptions. In contrast to the first round where the dominant strategy for members of $G_{1e}$is to choose strategy S, it is the dominant strategy to choose strategy M for members of G_{2e}. This crucial difference arises from the fact while a player in the first round reaches the highest human capital level given his education level by choosing strategy S, an even higher human capital level is reached by the same player in the second round by initially choosing strategy M. Since a player choosing strategy S would feature a lower human capital level than a player of the same education level choosing M, and given that promotions are scare if an internal competition is experienced, strategy S is strictly dominated by strategy M in these cases. It should also be noted that choosing M in these cases is also sufficient to defend a player against any external competition in the first round. The reason is that the players creating this external competition due to experiencing internal competition are forced to choose strategy S and the combination of strategy M together with a higher education level translates into a higher level of human capital.

Case 3: External competition in the first round
As in the game with one investment alternative it optimal for members of G_{1e+1} to avoid the external competition by choosing a strategy involving an investment. While the strategy N is strictly dominated, which of the two strategies M and S is chosen depends on the relative number of promotions available in the second round. Here three scenarios can be distinguished. The case of experiencing internal competition in the second round has already been explained in case 2 and it was shown that strategy M constitutes the dominant strategy for involved players. It was also pointed out that this choice is sufficient to defend the given player against the external competition in the first round. Players of group G_{1e+1} face a different situation when the available promotions in the second round are abundant. This can be understood as a situation, in which the number of the p promotions is larger than the number of players of G_{1e+1} plus the number of all players with a potentially higher education level than G_{1e+1}. In such a case both strategies involving an investment lead to the same outcome, because strategy S as well as strategy M lead to a human capital level that is higher than the players of a lower education level can reach. Hence both w^+ and b can be secured with either strategy S or strategy M. Again it helps players of G_{1e+1} that players of G_{1e} can only choose strategy S and not strategy M which would be more successful in the long run. Since the game ends after the allocation of the promotions there is no reason why strategy S should dominate strategy M or vice versa with the given utility function. With no further specification possible the optimal strategy can only be denoted with $\bar{N}$. The last possible case is that the available promotions are too scarce, which can be understood as a situation in which there are not even enough promotions available for the group of players with the next higher education level, denoted by G_{1e+2}. In comparison to the previous situation the different payoffs of strategy S and strategy M depends on the choice of members of G_{1e+2} and are not necessarily equal. While strategy S is dominated by strategy M for G_{1e+1} when $S_{G_{1e+2}} = \{\bar{M}\}$, as strategy M leads to a higher human capital level and hence better chances in the competition, the expected payoffs are equal for strategies S and M for G_{1e+1} when $S_{G_{1e+2}} = \{M\}$, because both strategies are then insufficient to enter the competition. Given the scarcity of promotions members of G_{1e+2} will experience internal competition and choose strategy M in equilibrium. Given this situation, $S_{G_{1e+1}} = \{\bar{N}\}$ as the exact investment choice does not matter.

Case 4: External Competition in the second round
The internal competition to secure one of the p promotions in the second round, that was described in case 2, also creates an external competition for these promotions for the group of players with the next higher education level G_{2e+1}. Since $S_{G_{2e}} = \{M\}$, the members of G_{2e} they threaten to surpass G_{2e+1} when $S_{G_{2e+1}} = \{N\}$. Even for $S_{G_{2e+1}} = \{S\}$ the players in G_{2e} and G_{2e+1} would reach the same human capital level in the end and the promotions will be randomly allocated among all of them. Only by choosing strategy M a player of G_{2e+1} can secure the payoff maximizing promotion. Hence in this situation choosing strategy M is the dominant strategy for G_{2e+1}.

Case 5: No investment due to a lack of perspective
Due to common knowledge of rationality all players know that $S_{G_{1e}} = \{S\}$. For the group of players with the next lower education level than G_{1e}, denoted by G_{1e-1}, it follows that there is no chance to secure one of the j jobs according to the logic presented in the first game. For members of G_{1e-1}

strategies S and M are strictly dominated by strategy N as the former lead to investment costs without any benefit. Moreover, there are also versions of the game where a group of players has an education level two levels below that of G_{1e}, which can be denoted G_{1e-2}. For members of G_{1e-2} none of their available strategies would allow them to reach a human capital level in the first round that allows them to compete for one of the j jobs.

Case 6: No investment due to a lack of competition
There are also versions of the game in which the education level of a group of players, which can be denoted G_{1e+2}, are two levels higher than that of G_{1e}. In this case, it becomes unnecessary for players of G_{1e+2} to invest as they will be able to secure both the higher wage and the bonus payment as not enough other players can reach their human capital level to compete. For this case to manifest, the number of jobs offering $w^+$and the number of available promotions needs to be sufficiently large to spare the player in question from any internal or external competition. While introducing the competition for promotions in the second round reduced the versions of the game where players with a high education level find no need to compete compared to the first game presented, these scenarios are still not eliminated as can be seen in Table 5. It should be noted however, that is partly the case, because in that particular scenario members of G_{1e} are trapped in the internal competition which forces them to play strategy S. Through this choice they cannot reach the human capital level of the players of G_{1e+2}, but with choosing strategy M that would have been possible. In that sense, the internal competition for the groups with lower education not only discourages the optimal long term development of the group in the competition but also ensures that more educated players see no need in further increasing their human capital.

4.3.3.4 Generalization of the Insights of the Game

Given the insights from the game regarding the driving forces behind an individual's decision, the conditions for a particular choice can be generalized for the version of the model with two investment alternatives. Let G_1 again denote those individuals with education level e^{++}, G_2 those with e^+ and G_3 the individuals with education level e. Similar to the approach when analysing the game it is important to distinguish six different scenarios. In general it is assumed that $0 < j < n$ and $p > 0$. The six scenarios are of interest which are summarised in Table 6.

The cases where $j = m; l$ and/or $p = m; l$ are ignored as they are become increasingly rare with a growing number of individuals and because the game showed that the power to predict behaviour is limited in this cases. The procedure to find the relevant conditions is similar to the first version of the game. In a first step the group of individuals will be considered that experiences external competition in round 1. Again it needs to be shown that an individual chooses to invest in the case with the worst possible combination by the other players for the payoff of investing and for the case with the best possible combination for not investing. In addition, depending on which group experiences further internal or external competition more conditions need to be specified. In the appendix A5 the most important equations are given for each scenario and the conditions are summarised in Table 6 below.

		Equilibrium	$G_3: e$	$G_2: e^+$	$G_3: e^{++}$
Scenario 1	$j < m$ $p < j$	(S, N, N)			$w^+ - w > \frac{m}{j}c - \frac{p}{j}b$ $w^+ - w > \frac{m}{m-j}c - \frac{m-p}{m-j}b$ $w^+ - w > \frac{p}{m-j}b$
Scenario 2	$m < j < (m+l)$ $p < m$	(M, S, N)		$w^+ - w > \frac{l}{j-m}c$ $w^+ - w > \frac{l}{l+m-j}c$	$b > \frac{m}{p}c$
Scenario 3	$m < j < (m+l)$ $m < p < j$	$\bar{N}, S, N)$		$w^+ - w > \frac{l}{j-m}c - \frac{p-m}{j-m}b$ $w^+ - w > \frac{l}{l+m-j}c - \frac{l+m-p}{l+m-j}b$ $w^+ - w > \frac{(j-m)p}{(l+m-j)l}b$	$b > \frac{m}{j-p}c$
Scenario 4	$(m+l) < j$ $p < m$	$(M, \bar{N}, S)$	$w^+ - w > \frac{n-m-l}{j-m-l}c$	$w^+ - w > \frac{n-m}{n-j}c$	$b > \frac{m}{p}c$
Scenario 5	$(m+l) < j$ $m < p < m+l$	(M, M, S)	$w^+ - w > \frac{n-m-l}{j-m-l}c$ $w^+ - w > \frac{n-m-l}{n-j}c$		$b > \frac{m}{m+l-p}c$
Scenario 6	$(m+l) < j$ $(m+l) < p < j$	$(N, \bar{N}, S)$	$w^+ - w > \frac{n-m-l}{j-m-l}c - \frac{p-m-l}{j-m-l}b$ $w^+ - w > \frac{p * (j-m-l)}{j(n-j)}b$	$w^+ - w > \frac{n-m}{n-j}c - \frac{n-p}{n-j}b$	

Table 6, Equilibrium conditions for the model with two investment alternatives, own creation

By analysing the conditions, which need to hold to make individuals from certain groups investment in meditation, further insights can be gained. Special attention should therefore given to scenarios 2, 4 and 5 as in each of them at least one group of individuals will choose to invest in meditation. For members of G_1 the question whether to invest depends on the relationship between the bonus payment and the investment costs. It can easily be seen that ceteribus paribus an increase in the bonus payment or a reduction in the investment cost will make an investment more likely. Moreover, in scenario 2 and scenario 4, which share the condition $p < m$, the term $\frac{m}{p}$ is relevant. The smaller this term is, the likelier an investment in meditation becomes. Hence, ceteribus paribus an increase in the available promotions increases the chances that an investment in meditation is beneficial. At the same time the lower the number of individuals with the highest education level, everything else being equal, the more likely they are to invest. The term $\frac{m}{p}$ could also be understood as a ratio and in that case the lower the number of individuals with the highest level of education in relation to the available number of promotions the more likely it is that these individuals will invest. In scenario 5, the term defining the relationship between the bonus payment and the investment cost is $\frac{m}{m+l-p}$. In this case, everything else being equal a larger number of individuals in G_1 and a larger number of individuals in G_2 increase the likelihood that an investment in meditation is made. Unlike before a lower number of promotions is helpful in this regard. While this seems contradictory it needs to be taken into account that there are more promotions available than individuals with the highest education level and therefore there will always be enough jobs for members of G_1 regardless how much p decreases. Unless of course it decreases so much that we leave the scenario 5 as $m < p < (m + l)$ is no longer the case.

4.3.3.5 Discussion of Insights

As in the first model the heterogeneity in the education level of the individuals establishes a hierarchy before any investment choice is made by lifting the individuals on different human capital levels. By creating this hierarchy before any investment choice is made the heterogeneity in education is the reason why internal competition arises, because in most cases there will not be enough jobs offering w^+ and promotions yielding an extra b for all the members of a particular group. The number of available jobs and of available promotions only defines which of the three groups will experience the internal competition in which round of competition.

The same four investment behaviours as in the model with one investment opportunity can be identified in this model, with the difference that the internal and external competition can be observed twice, once in the first round of competition and once in the second. The main driver of the behaviour of most individuals remains the internal competition in the first round. However, the choice of the group with the next higher education level is only in part determined by it as the competition faced in the second round also plays a crucial role. An effect that can be attributed to the introduction of a bonus payment in a second round, rather than to the different types of investments, is that in most combination of j and p higher educated individuals are more likely to also make an investment in order to secure the additional payment. In the first model with only one round these individuals tended to remain idle as their qualification was already high enough to secure the highest payoff.

The introduction of two different investment alternatives, however, also yields a number of interesting insights. First of all, experiencing the internal competition in the first round forces individuals to invest in the skill which is only beneficial in the short-term. The consequence is that these individuals sacrifice their opportunity to compete with higher educated individuals in the long-term. Yet, with another choice than the skill needed in the short-run they would be excluded from the competition altogether. It should be noted, that this also has consequences for the higher educated individuals in some cases. Since the lower educated individuals cannot invest in those skills that would allow them to compete with higher educated individuals, it is possible in some cases for the latter group to remain idle and not to invest increasing their human capital as no competition has to be feared. It follows that only those players who are capable of avoiding the internal competition in the first round are able to invest in the skill that has the highest long-term effect. Now it depends on the initial education level if an individual is experiencing internal competition in the first round. Since a higher initial education level leads to a lower likelihood to face such competition, it can be concluded that those individuals with a higher initial education are more likely to invest in the skill representing meditation in this model. Moreover, when the group of individuals with the highest education level experience internal competition in the second round, more available promotions and higher bonus payments increase the likelihood that the investment into meditation is made as it lowers the condition that has to hold for it to be beneficial.

4.4. Discussion of Assumptions

A number of assumptions have been made during the description of the model which deserve a brief discussion and the same is case for the assumptions made while solving the two games. First of all, it was assumed in the second version of the model that the cost for the two investment choices are equal. While this assumption was mainly made to be able to compare the two alternatives based on their effect, another reason is that it is difficult to judge, which investment actually leads to higher costs. Since there is no data on how much it costs to reduce cognitive biases through meditation, it is difficult to compare two alternatives. Without reliable data there are usually some reasons why the one investment alternative should be less expansive and vice versa. As both sides can be argued for, setting the costs equal constitutes the about the average of the two opinions.

Then the assumption was made that individuals can only make one investment in total. Compared with reality this assumptions seems odd, but it still fulfils an important function by forcing an individual to reveal which alternative he chooses if he may only choose one. It is also an interesting research problem to examine which combination of investments would be made if more investments were possible and when in time the different choices would be made when it is possible to invest in different rounds. However, this is left to further research. It was further assumed in the second version of the model that all investment choices are made before the first round of competition begins. As long as there is only one investment allowed in total it should not make a difference as all the investment choices are known to the players due to the common knowledge of rationality. In this sense, it is not necessary to wait for the second round to receive more information. In addition, in most cases the investment already serves a purpose in the first round and it makes little sense in these cases to delay it. Making the assumption as it is has the advantage of making the analysis easier as no dynamics are involved.

A crucial assumption that was made is that investing in meditation becomes more valuable in the second round of competition. When outlining the motivation for this second version it was pointed out that firms are likely to prefer certain specific skills when first hiring applicants, but that these skills become less valuable when moving up the hierarchy. In contrast to this decreasing value in the specific skill is the rise in value for meditation, which can be argued for based on two reasons. First, usually promotions lead to more responsibility and more decisions have to be made involving higher stakes. Another consequence is that there are less people higher up in the hierarchy who can correct wrong decisions. Due to these reasons employees who commit less errors in judgment are therefore becoming more valuable for the firm. Second, usually some time passes before a promotions are made and during this time the continuation of meditation leads to a larger degree of alteration. Indeed there is a positive relation between the degree of alteration and meditation practice until ten years of experienced is reached, while the greatest effect can be observed during the first four years of practice (Sedlemeier et al., 2012). The continued practice of the plasticity inducing activity tends to also lead to a higher degree of improvement for the functions it affects (Draganski et al., 2004) and hence in this case to an even greater reduction in judgment errors. Since a continuation of the practice is assumed, this would increase the costs a little, but still does not allow to judge which investment alternative has the higher cost as outlined above.

To find a unique equilibrium in the game a number of assumptions had to be made. In the version with one investment alternative the assumption that $w^{+} - w > 3c$ was sufficient. Since the alternative to invest in a certain skill was kept general to apply for many different cases, it is difficult to assess how realistic this assumption is. Yet, the positions higher up in the hierarchy in the professions involving a large degree of decision making tend to pay substantially more than those jobs on a lower level, especially when taking into account the large sum of bonus payments often paid to members of the board of a company. In comparison to this gap three times the investment costs is presumable rather low, but again an ultimate judgment on this matter requires data. The same problem applies for the version of the model with two investment alternatives for the investment costs in the specific skill. The problem to quantify the investment costs for the investment in meditation is even worse as such an investment has probably never consciously been made before and hence there exists no data on the question how much it costs to reach a level of meditation induced plasticity that suffices to reduce the occurrences of cognitive biases. In addition, the assumption $b > 3c$ often had to be made. As the differences in wages are even higher between two hierarchy levels at the top, this should not be a problem. This reasoning leads to problems for the necessary assumptions regarding the wage premium and the bonus payment though. Following the logic of the previous argument the bonus payment should be higher than the wage premium. However, when consulting Table A4 in the appendix sometimes the opposite needs to be assumed. This constitutes a problem, but at the same time the cases in question are not entirely realistic as nearly all individuals who secured a well-paid job in the first round are also promoted in the second. When introducing the assumption that only a specific proportion of individuals, that is not too high, gets promoted in the second round, the problem disappears and this new assumption at the same times seems to be realistic.

5. Discussion

5.1. Brief Literature Review and Discussion

Even though the focus on decision making and meditation may constitute a new field in the literature on human capital formation, similarities of the presented model can be observed in regard to existing research in the field of human capital formation in general. At the same time the presented model differs considerably from some of the main models in the field and these differences are also briefly outlined below to understand the different aims and approaches of the different contributions.

The standard model of human capital accumulation and wage growth developed Ben-Porath (1967) focuses on the maximization of the life-time income of an individual. The accumulated human capital constitutes a part of the function determining the individual's wage and it is analysed which level of human capital maximizes life-time utility and at which point in time the investment in human capital should be undertaken. In contrast to this approach, the model presented in this paper is not designed to investigate these aspects, but is instead constructed to analyse how workers with a heterogeneous education level behave in situation with strategic interdependence and when a long-term beneficial human capital investment alternative is chosen over an option that is beneficial in the short-term. The determination of the wage of a worker might be less sophisticated and does not directly follow from the exact human capital level. However, the wage in the presented model serves a different function as it is mainly needed to introduce competition among different individuals. Further differences include that in Ben-Porath's (1967) the strategic interdependence is missing and human capital investment alternatives are homogenous. In Becker's (1962) model, human capital is distinguished between general and firm specific, but is also addressing the question at which point in time to invest in human capital and for how long. In general, the literature on life cycle wage growth differs from the model presented in this thesis by its focus on the amount and timing of the investment in human capital and its effects on wage development over time. A recent summary of this field with heterogeneous human capital is given by Sanders and Taber (2012).

While the heterogeneity of job-seeking individuals in the presented model might also feature prominently in the signalling literature that traces back to the work of Spence (1973), the other aspects of this literature stand in a stark contrast to the presented model. In the signalling literature the problem of firms, to not be able to observe innate ability of job applicants, constitutes the main issue and in Spence's (1973) version investing into education is used to signal a high ability by those who choose to invest. The costs to invest in education differ for the individuals depending on their innate ability and when the difference in costs are high enough a separating equilibrium can be observed distinguishing those of high and those of low ability. In other cases a pooled equilibrium can emerge. In the presented model the observability of a given skill is not supposed to constitute a problem for the firm. It might be an interesting aspect to follow up on in future research, but for the present model, firms can observe the human capital level of workers and give the better paid jobs to those individuals with the highest human capital level, not the one with the highest innate ability. The assumption that an investment in meditation is observable can easily be made in the model, but the actual situation is more complex. In reality it would indeed be difficult to check if certain brain regions that are crucial in avoiding cognitive biases are larger than normal. To address this issue, it has been assumed that the market would provide certificates for meditators that participated long enough in courses to make it very likely that the effect of brain plasticity has manifested itself. While such a certificate can be used as evidence for an undertaken investment, it should not be understood as a signalling device as there is no signalling mechanism based on different costs. It also follows that the investment in human capital in the presented model is different to an investment in the signalling literature, because the costs for the investment are the same for all individuals and hence the investment does not signal any innate ability that could be observed in a separating equilibrium. The heterogeneity of workers in the model is used to investigate which type of worker will likely choose an investment that is beneficial in the long run, rather than to gain insights about what different investments could signal beyond the investment itself.

A research area that is closer to the presented model is the field of heterogeneous skills in human capital formation. A part of this field assumes that there are also different jobs requiring these heterogeneous skills was first illustrated by Roy (1951) by illustrating how villagers had to choose between the occupations of hunting and fishing. In a more recent paper Hamilton, Thisse and Zenou (2000) follow up on this idea when analysing an imperfect competition in the labour market by assuming that workers have heterogeneous skills, which are suited unequally well for different jobs. At the same time there is no ranking between these skills and all workers have the same level of human capital. In contrast, the presented model focuses on only one occupation, which features decision-making as the main part of the job, and also differs in the regard that workers feature different levels of human capital. For another part of this field of literature the main feature of the theory is that the heterogeneous skills can be divided in general and a specific human capital investment. One example is that in Becker's (1962) work the specific investment is only useful within one firm and not in others, while the general human capital is beneficial in the entire market. The choice between these two types of human capital investments also often involves a labour market in which job matching constitutes an important element. Grossman and Shapiro (1982) for instance developed a model to investigate if individuals rather choose to acquire human capital that specialises them in a certain task or invest in a more general kind of human capital even though the overall human capital level for the individuals did not differ. The analysis involves the trade-off that while a more specialised worker has the chance to earn a higher wage, his chances to find the good-matching job is smaller than when investing in the general skills. The authors find that individuals will invest more in the specific skills when uncertainty increases. If uncertainty is not involved, individuals will choose to invest in the specific skill (Rosen, 1983). Kim (1989) develops a similar model, in which individuals choose to invest in the breath or depth of their human capital. Again as there is job matching involved trade-offs occur in this investment choice and the author shows that, as the size of the labour market increases, workers choose to invest more in the depth of their skills. While Ichida (2011) is one of the rare cases in which individuals can invest in their general human capital level and at the same time have the choice to invest in two different specific skills, the analysis of the situation again only focuses on the question how to optimally cope with uncertainty regarding what type of skill is needed. The trade-off between the general and specific human capital investment can not only be analysed in the context of job matching in the labour market, but also be studied for the employees of a specific firm. In Amend and Herbst (2008) employees choose between these two types of investments depending on their belief what their firm will need in the future. In general, investigating the choice of worker between different human capital investments in this research field is similar to the analysis conducted in this thesis. Yet, the dimension in which the two investment alternatives differ is different. While in the existing literature the trade-off between general and specific skills is key, in the presented model two specific skills are offered for which the crucial difference is the point in time, when the skill is preferred by the firm, either in the short or in the long run. The former combination basically involves an analysis how a worker hedges his bets for different possible scenarios. In contrast, the question addressed by this thesis is when which type of worker is under what conditions willing to choose the long-term investment.

Interesting insights regarding the choice between investments that are beneficial in the short term and those in the long term can be found in the literature on the microeconometric evaluation of job-market trainings. The context is certainly different as the relevant population are unemployed individuals, but the available choices are similar. Osikominu (2009) evaluates the different effects of short-term job-oriented training programmes and more long-term human capital intensive training programmes. The author finds that while the short-term programmes leads to the unemployed quicker finding a job, the long-term programme ultimately leads to higher earnings and longer employment spells. Yet, from a fiscal perspective only the short-term programmes are cost effective in the short run. These findings are similar to the insights of the presented model as in both cases the long-term solution would ultimately be better, in higher wages for the former unemployed and in the model a resulting higher human capital level, there are certain constraints which push individuals to choose the short-term option, which are financial reasons for the unemployed or experiencing internal competition for the individuals in the presented model.

In general, the economic literature on human capital appears to mainly be concerned about the choices of the individual and strategic interdependence between different individuals is rarely encountered. In addition, this author could not find any contributions in the area of human capital in which the choice of on group of individuals restricts the reasonable choice set of another group, but it cannot be ruled out that such studies already exist. In any case, this thesis adds to this literature a scenario in which individuals who are heterogeneous in their education level compete for scarce well-paid jobs and have two investment alternatives, which differ in their effect, to increase their human capital level.

5.2. Why Meditation is economically different from Education

In the beginning of this thesis it has been argued that meditation should be seen as a complement to education when it comes to the task of decision making. Since different levels of education and meditation skills could result in the same level of human capital, it could have been concluded that meditation is actually a substitute for education. However, meditation should not be regarded as a substitute for education for three main reasons.

First of all, there is the difference between the two concepts from a neuroscientific point of view. When education is understood of accumulating knowledge, this is a process that occurs that micro-level of the brain structure as knowledge is encoded by strengthening the connection between neurons. In contrast, meditation is capable of inducing brain plasticity effects, which change the macro-structure of the brain as some brain areas increase in size of volume. These are two different neuroscientific processes with different outcomes and the one process cannot simply produce the outcome of the other. However, it is not yet known yet if receiving a general education might also induce brain plasticity and further research is necessary here.

The second reasons is that these two types of investment serve different purposes when increasing the quality of decision making. To see this, consider the two extreme cases, a complete bias free individual with no education and a well-educated individual falling occasionally prey to cognitive biases. The former will perform better when the optimal decisions can be found by pure application of logic, while the latter will outperform the former when context knowledge is required even though his decisions will at times deviate from logical norms. None of the two skills can simply replace the other both knowledge and correctly applying logic is needed to make good decisions. Especially in the areas where decision making is needed such as business management, politics or medicine, the knowledge provided through education is needed and at the same time the performance of individuals could be improved if their decisions were less influenced by cognitive biases.

The third reason is that even though different combinations of education and meditation levels can lead to the same human capital level, their role in the economic model presented differs considerably and they are not substitutes. Individuals enter the model with different education levels and this indicates that there is some limit to the education level an individual can reach. The easiest explanation for such a limit would be natural ability as some individuals are simply not intelligent enough to reach the next higher level. In this case the assumption is necessary that firms care about the general human capital level when hiring the individuals rather than the innate ability which would be signalled through education. Then his education level defines an individual's place in the hierarchy and hence which type of competition the individual will face. It also follows, ignoring costs to education for the moment, that an individual will choose to get his maximum level of education as this improves this improves his perspectives in the job competition. In contrast, meditation is only an opportunity that is presented to an individual after his place in the hierarchy has been set. This opportunity is open to every player and there are no limits on for instance natural ability which individual can choose this investment. Since the level of education is determined first, meditation only serves as an addition to the human capital that already exists. In addition, a trait of meditation is that its benefits only materialize in the long-term, which the benefits of education remain constant over time in the model. Last but not least, an attempted substitution would in most cases break down due to the sequence of the investments. If an individual would like to choose to instead of receiving his maximum level of education to settle for an education level one level below and instead invest in meditation his plans are doomed for the following reason. By settling for a lower education level the individual would likely face internal competition in the first round and choosing M would then not prove feasible when maximizing payoffs or worse the individual would fall into the group with an education level below the group that experiences internal competition and would hence settle for no investment at all. For the same reasons presented, an investment in skill is also no substitute for education.

5.3. Contributions of this Thesis

This thesis makes a number of contributions to the scientific literature in general and to the economic literature on human capital in particular. The first contribution is to connect the two fields of meditation research and the field of cognitive biases as well as providing neuroscientific, theoretical evidence that it is very plausible that cognitive biases can be reduced through the practice of meditation. This insight is particularly valuable as many cognitive biases remain difficult to correct and because science has not been able yet to find to find one solution that is applicable to the majority of those biases that are difficult to correct.

The next contribution is to expand the research field of human capital by introducing the assumption that it is possible for individuals to invest into an alteration of their brain. This new assumptions opens a new area in the field by allowing individuals to increase their human capital by making investments to address evolutionary adaptations, which can at times have negative impacts. This new subfield should be distinguished from the existing body of research, because its underlying assumption differs and is not covered by assumptions made previously in the field. The existing assumptions rest on the idea that human capital can be increased through learning and skill training, but it has been pointed out by this thesis that both aspects cannot affect the automatic processes that create costs in some circumstances while being otherwise beneficial.

The third contribution of this thesis is to add to the literature of this new subfield by addressing the evolutionary adaptation leading to cognitive biases. More specific, it is investigated on a theoretical basis for which individuals it may under which conditions be beneficial to invest in a reduction of cognitive biases when competing for scarce but well-paid jobs in labour market, where decision making constitutes a key aspects. Through the insight that such an investment tends to be more beneficial for those individuals that are already better qualified than their competitors, this thesis provides a first idea which group of people could be interested in such an investment possibility.

The last contribution is the model developed in this thesis. While it was built to resemble the investment alternative of meditation and the particular labour market where decision-making plays an important role, the model can also be applied to other human capital investment contexts. The key characteristics of individuals with heterogeneous levels of education and a hierarchical job structure, with competition in several stages, appear to also constitute key elements in other the labour market of other professions. The presented model may then prove helpful, when an individual faces the choice between an investment that is beneficial in the short-run and one that is better in the long-run. While the long-run investment was supposed to be meditation, it can easily be replaced by a different investment alternative, as long as it has some feature that makes it less beneficial in the short-run, but better in the long-run. The alternative investment in a skill was already held rather general in this model and it should therefore not constitute a problem to apply it in a different context.

5.4. Suggested Further Research

Despite the previously mentioned contribution, many questions arose during the process of writing this thesis, that could not be addressed within the scope if this thesis. Yet, these ideas may serve as an inspiration for further research. First, the ideas that involve further investigation into the phenomenon of brain plasticity will be outlined. Second, thoughts regarding a welfare analysis of the proposed investment are presented, before it is outlined which other use meditation could have. As a fourth point, potential additions to the presented model are highlighted and last but not least, future research for the field of human capital is suggested.

Since this thesis provided theoretical evidence that meditation can lead to a reduction of cognitive biases through inducing brain plasticity, it would be of interest to find out if this relationship can be shown empirically in a setting that goes beyond investigating a particular bias as Kiken and Shook (2011) and Hafenbrack et al. (2104) have already done. The extend, to which this is possible, also constitutes an aspect that deserves further attention, because the calculated effect sizes in Fox et al. (2014) do give some indication of the magnitude of the detected effects, but it is unclear how this translates into the case of reducing biases. It should also be noted that inducing brain plasticity in one area of the brain can potentially have detrimental effects for other areas, because an increase in size of one area leads to a decrease in another area when the available space remains the same. Nudo et al. (1996) report for instance that while the sensitivity of a monkey's fingertips increased by the given exercise, the sensitivity in their arms decreased as a result. These potential drawbacks should be investigated empirically, even though their effect is likely to be negligible. Moreover, it is encouraged to conduct an empirical study to find out if the process of receiving an education also induces plastic changes in the brain. Schlegel, Rudelson and Tse (2012) have shown that these brain plasticity occurs when subjects study a second language. Just as the brain is used more than usual during everyday life when meditating or learning a new language, the same holds for studying. It appears plausible that this training should also have implications for the macro-level, not just for the micro-level responsible for encoding new knowledge.

A welfare analysis of the proposed investment is needed and several perspectives should to be taken into account here. First of all, there is the individual, who faces the choice of investing into meditation. In the presented model, the individuals incurs certain costs from the investment, which makes sense as it will require time and potential instruction costs. At the same time meditation offers several other benefits than reducing biases. This was not taken into account in the model as this could also be the case for other skills such as learning a language. This might be beneficial at work, but could also have private benefits when travelling for instance. Yet, these benefits appear to be particularly pronounced for meditation and should be considered in greater detail. As meditation raises the current well-being (Sedlemeier et al, 2012), reduces stress (Tang et al., 2015) and improves an individual's health (Davidson et al., 2003), not to mention the private benefits of avoiding cognitive biases and improve insightful problem solving (Ostafin & Kassman, 2012), it might be the case that these benefits already offset the costs involved. If that is the case it would certainly influence the investment decision. The perspective of the firm also needs to be addressed. In particular it has to be evaluated how large the benefit of avoiding cognitive biases in decision-making is for the firm. Then there is the group of individuals which are no part of the model, but would benefit if other individuals make better decisions as their life is affected by the outcome. Consider for example the patients receiving a better treatment or individuals in a natural disaster when the people in charge make better choices. These benefits should also be taken into account depending on the findings of such an investigation it might be reasonable to subsidize the practice of meditation if it yields benefits to a wide population and the investment would not be made otherwise because the costs involved are too high.

Due to the multiple benefits reported for the practice of meditation it could also be interesting to consider where it could make economic sense to replace current programmes addressing a certain problem through the practice of meditation, because it may achieve the same outcome with lower costs. While the clinical field is a natural starting point to investigate if there are efficiency gains to be realized (see Davidson & Begley, 2013) it might also be possible in other areas. For instance it might constitute a problem for long-term unemployed to focus over a longer period of time when becoming employed again. Here concentrative meditation techniques might help to focus over a longer period of time and replace possibly rather expensive training programmes which aim for the same effect. At the same time it might of interest to analyse the investment decision to reduce cognitive biases from the firm's perspective instead of from the viewpoint of the individual. After all firms usually send their employees to trainings to enhance their skills and it could be the case that it might be the best strategy for the firm to hire those individuals with the highest education level and then to teach them meditation instead of hiring those individuals who already meditate and have a lower education level.

While the presented model served its purpose of indicating which individuals are more likely to make the proposed investment into meditation, there are several aspects that could be changed to create an even more realistic model or to gain further insights. Currently the education level is given by discrete steps but it could also be given by certain continuous distribution. The easiest case constitutes a uniform distribution, but another distribution might be more accurate, while at the same time more complex. In the presented model individual differences in intelligence were only indirectly considered by assuming different levels of education. Yet, it might be of interest to understand what role intelligence plays when it leads to different skill investment costs among the individuals. When expanding the model to include intelligence as a factor, it should be kept in mind that a more distinctive differentiation needs to be made for the investment into meditation, because more intelligent players are already less likely to be affected by cognitive biases (Kahneman & Frederick, 2002, p. 56). Another idea could be to make the assumption that firms have difficulties to observe the two investment alternatives equally well, but this would lead more to the literature going back to Spence (1973). Since Tang et al. (2015) point out that meditation might not have the desired effect for everyone, it could also be analysed how individuals and firms address this uncertainty.

It follows from the introduction of the assumption that investing into a brain alteration is possible into the literature of human capital that the following two aspects should receive greater attention in future research. First, it should be considered which other evolutionary adaptations with certain shortcomings could be addressed and investigate for which individuals it might be of interest and if it is overall beneficial. Second, the concept of multi-stage investment in human capital (see Cunha et al., 2006) could also be applied to adults rather than to focus solely on children.

6. Conclusion

So far the existing literature on human capital investment has failed to take into account that individuals can make an investment into altering the structure of their brain to address evolutionary adaptations that are overall beneficial but impose costs in certain situations. One of these adaptations is the use of heuristics in decision making, which produces cognitive biases as their use leads to grave and systematic errors in judgment. The first aim of this thesis is to provide neuroscientific evidence that an alteration in the brain through a meditation induced brain plasticity has the potential to reduce the occurrences of these biases. To this end, it is first outlined which brain regions are found to be consistently altered through meditating. As an alteration of a given brain area corresponds to an improvement in its function, it is then explained which functions the altered regions fulfil and how an improved version of the brain can address the occurrence of cognitive biases. This evidence based on the phenomenon of brain plasticity is supplemented by meditation studies, which show that meditation has proven to have certain effects, which in turn indicate the potential of meditation to address cognitive biases.

After it has been established that meditation can reduce cognitive biases, it is the second aim of this thesis to find out, for which individuals such an investment into meditation could be beneficial, and answer the research question, how the level of education and the degree of competition influence the willingness to invest. To provide an answer, a model is developed in which individuals who are heterogeneous in their level of education compete for well-paid but scarce jobs in a labour market, in which firms value human capital in the area of decision making. Two versions of this model are introduced. In the first version individuals face the choice whether to invest in a certain skill to increase their human capital level. This version of the model serves the purpose to understand the driving forces behind the decision of the individuals with different levels of education. In the second version individuals have two investment alternatives, which differ in the timing and level of their effect on the human capital level of the individual. One investment alternative is modelled to resemble the investment into meditation. To understand the behaviour of the individuals in both versions of the model, the latter are translated into an economic game to highlight the strategic interdependence between individuals and to find the behaviour in equilibrium by applying the solution concept of IESDS. After detecting the driving patterns of investment behaviour, this insight is used to generalize the findings from the game for the two versions of the model. It is found that an investment in meditation to reduce cognitive bias is only interesting for individuals with a level of education which is high enough to spare them from competition early on in their career.

This thesis makes the following contributions to the existing scientific literature. It provides evidence suggesting that it is very plausible that practising meditation has the potential to reduce cognitive biases. Moreover, it expands the set of assumptions in the field of human capital investment by allowing for investments into an alteration of the brain and shows that especially those individuals with a high enough level of education may be interested in investing into meditation to improve their decision-making skills. The presented model is also general enough to be of use in different contexts of human capital investment when analysing investment behaviour in a situation where two alternatives differ in the timing of their effect. Future research should focus on showing empirically what is argued in this thesis theoretically regarding the potential of meditation. In addition, a welfare analysis of the proposed investment should be conducted and the presented model further developed.

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Appendix

A1 IESDS application in the game with one investment opportunity

Let S_g^k denote the strategy set of group g that survives k rounds of IESDS. Moreover, let $S_g^0 = S_g = \{N, S\}$ for all $g \in \{G_1, G_2, G_3\}$. The version of the game for which the procedure of IESDS will be explained below is $j = 4$.

Round 1:

It can be shown that for players of G_2 strategy N is strictly dominated by strategy S under certain assumptions as will be shown below. To show that a strategy is indeed strictly dominated, it needs to be shown that this is true in all possible cases. In the following this will be attempted to be proven for all combinations of choices the relevant players.

Case 1: assume that $S_{-iG_2} = \{S\}$

Case 1.1: assume that $S_{G_1} = \{S\}$

$$v_i(S,S,S,\cdot) > v_i(N,S,S,\cdot)$$
$$\frac{1}{3}w^+ + \frac{2}{3}w - c > w$$
$$w^+ - w > 3c$$

Case 1.2. assume that $S_{G_1} = \{N\}$

$$v_i(S,N,S,\cdot) > v_i(N,N,S,\cdot)$$
$$\frac{2}{3}w^+ + \frac{1}{3}w - c > w$$
$$w^+ - w > \frac{3}{2}c$$

Case 2: assume that $S_{-iG_2} = \{N\}$

Case 2.1: assume that $S_{G_3} = \{S\}$

$$v_i(S,\cdot,N,S) > v_i(N,\cdot,N,S)$$
$$w^+ - c > \frac{1}{6}w^+ + \frac{5}{6}w$$
$$w^+ - w > \frac{6}{5}c$$

Case 2.2: assume that $S_{G_3} = \{N\}$

$$v_i(S,\cdot,N,N) > (N,\cdot,N,N)$$
$$w^+ - c > \frac{1}{3}w^+ + \frac{2}{3}w$$
$$w^+ - w > \frac{3}{2}c$$

For members of G_2 strtaegy N is strictly dominated by strategy S if $w^+ - w > 3c$ is assumed. Hence, $S_{G_3}^1 = \{N, S\}$, $S_{G_2}^1 = \{S\}$ and $S_{G_1}^1 = \{N, S\}$.

Round 2:

It can be shown that for members of G_3 strategy S is strictly dominated by strategy N:

$$v_i(N,\cdot,S,\cdot) > v_i(S,\cdot,S,\cdot)$$
$$w > w - c$$

It can be shown that for members of G_1 strategy N is strictly dominated. To prove this two cases need to be taken into consideration.

Case 1: assume $S_{-iG_1} = \{S\}$, then:

$$v_i(S,S,S,\cdot) > v_i(N,S,S,\cdot)$$
$$w^+ - c > \frac{1}{4}w^+ + \frac{3}{4}w$$
$$w^+ - w > \frac{4}{3}c$$

Case 2: assume $S_{-iG_1} = \{N\}$, then:

$$v_i(S,N,S,\cdot) > v_i(N,N,S,\cdot)$$
$$w^+ - c > \frac{2}{3}w^+ + \frac{1}{3}w$$
$$w^+ - w > 3c$$

For members of G_1 strategy N is strictly dominated by strategy S if $w^+ - w > 3c$ is assumed.

Hence, $S_{G_3}^2 = \{N\}$, $S_{G_2}^2 = \{S\}$ and $S_{G_1}^2 = \{S\}$.

Any strategy profile $S^{ES} = (S_{G_1}^{ES}, S_{G_2}^{ES}, S_{G_3}^{ES})$ that survives the process of IESDS is called an iterated-elimination equilibrium (Tadelis, 2013, p. 65).

For the version of the game with $= 4$, $S^{ES} = (S, S, N)$. The necessary condition is $w^+ - w > 3c$.

A2 General equilibrium conditions for one investment alternative

Scenario 1:

Individuals belonging to G_1 will invest if both of the following equations hold:

G_1 worst case scenario for investing:

$$v_i(S, S, \cdot, \cdot) > v_i(N, S, \cdot, \cdot)$$
$$\frac{j}{m}w^+ + \left(1 - \frac{j}{m}\right)w - c > w$$
$$w^+ - w > \frac{m}{j}c$$

G_1 best case scenario for not investing is:

$$v_i(S, N, N, \cdot) > v_i(N, N, N, \cdot)$$
$$w^+ - c > \frac{j}{m}w^+ + \left(1 - \frac{j}{m}\right)w$$
$$w^+ - w > \frac{m}{m-j}\,c$$

Scenario 2:

Individuals belonging to G_2 will invest if both of the following equations hold:

G_2 worst case scenario for investing:

$$v_i(S, S, S, \cdot) > v_i(N, S, S, \cdot)$$
$$\frac{j-m}{n}w^+ + \left(1 - \frac{j-m}{n}\right)w - c > w$$
$$w^+ - w > \frac{l}{j-m}\,c$$

G_2 best case scenario for not investing:

$$v_i(S, \cdot, N, N) > v_i(N, \cdot, N, N)$$
$$w^+ - c > \frac{j-m}{l}w^+ + \left(1 - \frac{j-m}{l}\right)w$$
$$w^+ - w > \frac{l}{l+m-j}c$$

Individuals belonging to G_1 will invest if it is beneficial for them, so if:

$$v_i(S, N, S, \cdot) > v_i(N, N, S, \cdot)$$
$$w^+ - c > \frac{j}{l+m}w^+ + \left(1 - \frac{j}{l+m}\right)w$$
$$w^+ - w > \frac{l+m}{l+m-j}c$$

It should be noted that the second assumption for $G_2$is covered by the assumption for G_1.

Scenario 3:

Individuals belonging to G_2 will invest if both of the following equations hold

G_3 worst case for investing:

$$v_i(S, \cdot, S, S) > v_i(N, \cdot, S, S)$$
$$\frac{j-m-l}{n-m-l}w^+ + \left(1 - \frac{j-m-l}{n-m-l}\right)w - c > w$$
$$w^+ - w > \frac{n-m-l}{j-m-l}c$$

G_3 best case for not investing:

$$v_i(S, \cdot, , N) > v_i(N, \cdot, \cdot, N)$$
$$w^+ - c > \frac{j-m-l}{n-m-l}w^+ + \left(1 - \frac{j-m-l}{n-m-l}\right)w$$
$$w^+ - w > \frac{n-m-l}{n-j}c$$

Individuals from G_2 will invest if it is beneficial for them, so if:

$$v_i(S,\cdot,S,S) > v_i(N,\cdot,S,S)$$

$$w^+ - c > \frac{j-m-(l-1)}{n-m-(l-1)}w^+ + \left(1 - \frac{j-m-(l-1)}{n-m-(l-1)}\right)w$$

$$w^+ - w > \frac{n+1-m-l}{n-j}\,c$$

It should again be noted that the second assumption from G_3 is ncovered by the assumption of G_2.

A3 IESDS application in the game with two investment alternatives

Let S_g^k denote the strategy set of group g that survives k rounds of IESDS. Moreover, let $S_g^0 = S_g = \{\mathrm{M}, N, S\}$ for all $g \in \{G_1, G_2, G_3\}$. The version of the game for which the procedure of IESDS will be explained below is j= 5 and p = 2.

Round 1:

It can be shown that for players of G_2 strategy N is strictly dominated by strategy S under certain assumptions as will be shown below. To show that a strategy is indeed strictly dominated, it needs to be shown that this is true in all possible cases. In the following this will be attempted to be proven for all combinations of choices the relevant players.

Case 1: assume $S_{-iG_2} = \{S\}$

Case 1.1: assume $S_{G_1} = \{\bar{N}\}$, then

$$v_i(S,\bar{N},S,\cdot) > v_i(N,\bar{N},S,\cdot)$$

$$\frac{2}{3}w^+ + \frac{1}{3}w - c > w$$

$$w^+ - w > \frac{3}{2}c$$

Case 1.2: assume $S_{G_1} = \{N\}$, then

$$v_i(S,N,S,\cdot) > v_i(N,N,S,\cdot)$$

$$\frac{5}{6}w^+ + \frac{1}{6}w + \frac{1}{3}b - c > w$$

$$w^+ - w > \frac{6}{5}c - \frac{2}{5}b$$

Case 2: assume $S_{-iG_2} = \{M\}$

Case 2.1: assume $S_{G_1} = \{M\}$, then

$$v_i(S,M,M,\cdot) > v_i(N,M,M,\cdot)$$

$$w^+ - c > w$$

$$w^+ - w > c$$

Case 2.2: assume $S_{G_1} = \{S\}$, then

$$v_i(S,S,M,\cdot) > v_i(N,S,M,\cdot)$$

$$w^+ - c > w$$

$$w^+ - w > c$$

Case 2.3: assume $S_{G_1} = \{N\}$, then

$$v_i(S,N,M,\cdot) > v_i(N,N,M,\cdot)$$

$$w^+ + \frac{1}{4}b - c > w$$

$$w^+ - w > c - \frac{1}{4}b$$

Case 3: assume $S_{-iG_2} = \{N\}$

Case 3.1: assume $S_{G_1} = \{\overline{N}\}; S_{G_3} = \{\bar{S}\}$

$$(S, \overline{N}, N, \bar{S}) > (N, \overline{N}, N, \bar{S})$$
$$w^+ - c > \frac{2}{3}w^+ - \frac{1}{3}w$$
$$w^+ - w > 3c$$

Case 3.2: assume $S_{G_1} = \{\overline{N}\}; S_{G_3} = \{S\}$

$$(S, \overline{N}, N, S) > (N, \overline{N}, N, S)$$
$$w^+ - c > \frac{1}{3}w^+ - \frac{2}{3}w$$
$$w^+ - w > \frac{3}{2}c$$

Case 3.3: assume $S_{G_1} = \{N\}; S_{G_3} = \{\bar{S}\}$

$$(S, N, N, \bar{S}) > (N, N, N, \bar{S})$$
$$w^+ + \frac{1}{2}b - c > \frac{2}{3}w^+ - \frac{1}{3}w$$
$$w^+ - w > 3c - \frac{3}{2}b$$

Case 3.4: assume $S_{G_1} = \{N\}; S_{G_3} = \{S\}$

$$(S, N, N, S) > (N, N, N, S)$$
$$w^+ + \frac{1}{2}b - c > \frac{1}{3}w^+ - \frac{2}{3}w$$
$$w^+ - w > \frac{3}{2}c - \frac{3}{4}b$$

It becomes clear that for G_2 N is strictly dominated by S if $w^+ - w > 3c$. No strict dominance can be observed between strategy S and strategy M as strategy M would for instance be optimal when $S_{G_3} = \{\cdot\}, S_{-iG_2} = \{N\}$ and $S_{G_1} = \{S\}$. And to play S when $S_{G_3} = \{\cdot\}, S_{-iG_2} = \{M\}$ and $S_{G_1} = \{M\}$.

At the same time it can be shown that for G_1N is strictly dominated by M under certain conditions. Again it is necessary to prove this for all the different possible cases:

Case 1: assume $S_{-iG_1} = \{M\}$

Case 1.1: assume $S_{G_2} = \{\bar{S}\}$ then

$$v_i(M, M, \bar{S}, \cdot) > v_i(N, M, \bar{S}, \cdot)$$
$$w^+ + \frac{2}{3}b - c > w^+$$
$$b > \frac{3}{2}c$$

Case 1.2: assume $S_{G_2} = \{S\}$ then

$$v_i(M, M, S, \cdot) > v_i(N, M, S, \cdot)$$
$$w^+ + \frac{2}{3}b - c > \frac{3}{4}w^+ + \frac{1}{4}w$$
$$w^+ - w > 4c - \frac{8}{3}b$$

Case 2: assume $S_{-iG_1} = \{S\}$

Case 2.1: assume $S_{G_2} = \{\bar{S}\}$ then

$$v_i(M, S, \bar{S}, \cdot) > v_i(N, S, \bar{S}, \cdot)$$
$$w^+ + b - c > w^+$$
$$b > c$$

Case 2.2: assume $S_{G_2} = \{S\}$ then

$$v_i(M, S, S, \cdot) > v_i(N, S, S,)$$
$$w^+ + b - c > \frac{3}{4}w^+ + \frac{1}{4}w$$
$$w^+ - w > 4c - 4b$$

Case 3: assume $S_{-iG_1} = \{N\}$

Case 3.1: assume $S_{G_2} = \{M\}$ then

$$v_i(M, N, M, \cdot) > v_i(N, N, M, \cdot)$$
$$w^+ + b - c > w^+$$
$$b > c$$

Case 3.2: assume $S_{G_2} = \{S\}$ then

$$v_i(M, N, S, \cdot) > v_i(N, N, S,)$$
$$w^+ + b - c > \frac{5}{6}w^+ + \frac{1}{6}w + \frac{1}{3}b$$
$$w^+ - w > 6c - 4b$$

Case 3.3: assume $S_{G_2} = \{N\}$ then

$$v_i(M, N, N, \cdot) > v_i(N, N, N, \cdot)$$
$$w^+ + b - c > w^+ + \frac{2}{3}b$$
$$b > 3c$$

Hence strategy N is strictly dominated by strategy M if $b > 3c$. It should be noted though that the result will hold in the equilibrium with a lesser assumption as $S_{G_2} = \{N\}$ which was assumed in the last case has been eliminated in the first round as well. In the first round it cannot be shown that S is also strictly dominated by M, because in the scenario that $S_{-iG_1} = \{N\}, S_{G_2} = \{\bar{M}\}$ and $S_{G_3} = \{\cdot\}$ the expected payoffs are identical for the two strategies.

Last but not least it can be shown that for G_3 strategy M is strictly dominated by strategy N:

$$v_i(N,\cdot,\cdot,\cdot) > v_i(M,\cdot,\cdot,\cdot)$$
$$w > w - c$$
$$c > 0$$

No strict dominance can be found for the remaining strategies as strategy S is for example better when $S_{-iG_3} = \{\cdot\}, S_{G_2} = \{N\}$ and $S_{G_1} = \{\cdot\}$ and strategy N leads to a higher payoff if $S_{-iG_3} = \{\cdot\}, S_{G_2} = \{\bar{N}\}$ and $S_{G_1} = \{\cdot\}$.

The first round of iteration can be summarised be pointing out the remaining strategies for each group of players: $S^1_{G_3} = \{N, S\}$, $S^1_{G_2} = \{M, S\}$ and $S^1_{G_1} = \{M, S\}$.

Round 2

It can be shown that for members of G_2 strategy M is strictly dominated by strategy S. This was not the case before in round one as for players of G_2 it would have been optimal to play strategy M rather than S when $S_{G_3} = \{\cdot\}, S_{-iG_2} = \{N\}$ and $S_{G_1} = \{S\}$. However, $S_{-iG_2} = \{N\}$ has been ruled out in round 1 of the iteration process. Still, to show that M is strictly dominated again several cases need to be considered.

Case 1: assume $S_{-iG_2} = \{S\}$

In addition, it is known that $S_{G_1} = \{\bar{N}\}$

$$v_i(S,\bar{N},S,\cdot) > v_i(M,\bar{N},S,\cdot)$$
$$\frac{2}{3}w^+ + \frac{1}{3}w - c > w - c$$
$$w^+ - w > 0$$

Case 2: assume $S_{-iG_2} = \{M\}$

Case 2.1: assume $S_{G_1} = \{M\}$, then

$$v_i(S,M,M,\cdot) > v_i(M,M,M,\cdot)$$
$$w^+ - c > \frac{2}{3}w^+ + \frac{1}{3}w - c$$
$$w^+ - w > 0$$

Case 2.2: assume $S_{G_1} = \{S\}$, then

$$v_i(S,S,M,\cdot) > v_i(M,S,M,\cdot)$$
$$w^+ - c > \frac{2}{3}w^+ + \frac{1}{3}w + \frac{4}{15}b - c$$
$$w^+ - w > \frac{4}{5}b$$

It becomes clear that for G_2 M is strictly dominated by S. For the moment this is the case as long as $w^+ - w > \frac{4}{5}b$. However, the decision of members of G_1 have not been completely analysed yet and it will be shown later that $S_{G_1} = \{S\}$ is strictly dominated and hence this assumption does not need to be made.

For players from G_3 it can be shown that strategies S is strictly dominated by strategy N since round 1 of the elimination process showed that $S_{G_2} = \{\bar{N}\}$:

$$v_i(N,\cdot,\bar{N},\cdot) > v_i(\bar{N},\cdot,\bar{N},\cdot)$$
$$w > w - c$$
$$c > 0$$

For players of G_1 strategy S is strictly dominated by strategy M as the only scenario where they led to equal expected payoffs has been eliminated in the first round of the elimination process. Again a number of cases have to be considered.

Case 1: assume $S_{-iG_1} = \{M\}$, then

$$v_i(M,M,\cdot,\cdot) > v_i(S,M,\cdot,\cdot)$$
$$w^+ + \frac{2}{3}b - c > w^+ - c$$
$$b > 0$$

Case 2: assume $S_{-iG_1} = \{S\}$

Case 2.1: assume $S_{G_2} = \{M\}$ then

$$v_i(M,S,M,\cdot) > v_i(S,S,M,)$$
$$w^+ + b - c > w^+ + \frac{2}{5}b - c$$
$$b > 0$$

Case 2.1: assume $S_{G_2} = \{S\}$ then

$$v_i(M,S,S,\cdot) > v_i(S,S,S,)$$
$$w^+ + b - c > w^+ + \frac{2}{3}b - c$$
$$b > 0$$

Hence for members of G_1 strategy S is dominated by strategy M without any further conditions.

To conclude, for the version of the game with $j = 5$ and $p = 2$ the iterated elimination equilibrium is $S^{ES} = (M,S,N)$. The necessary conditions are $w^+ - w > 3c$ and $b > \frac{3}{2}c$.

A4 Conditions for equilibrium in game 2

	$p = 7$	$p = 6$	$p = 5$	$p = 4$	$p = 3$	$p = 2$	$p = 1$
$j = 2$							(S, N, N) $w^+ - w > 3c - 2b$ $w^+ - w > b$
$j = 3$						(M, N, N) $w^+ - w > \frac{4}{3}c - \frac{8}{9}b$ $b > 3c$	(M, N, N) $w^+ - w > \frac{4}{3}c - \frac{4}{9}b$ $b > 3c$
$j = 4$					$(\bar{N}, S, N)$ $w^+ - w > 3c$ $b > 3c$	(M, S, N) $w^+ - w > 3c$ $b > 1.5c$	(M, S, N) $w^+ - w > 3c$ $b > 3c$
$j = 5$				$(\bar{N}, S, N)$ $w^+ - w > 3c - 2b$ $b > 3c$ $w^+ - w > \frac{8}{5} b$	$(\bar{N}, S, N)$ $w^+ - w > 3c$ $b > c$ $w^+ - w > \frac{6}{5} b$	(M, S, N) $w^+ - w > 3c$ $b > 1.5c$	(M, S, N) $w^+ - w > 3c$ $b > 3c$
$j = 6$			(M, M, N) $w^+ - w > \frac{4}{3}c - \frac{8}{9}b$ $b > 3c$	(M, M, N) $w^+ - w > \frac{4}{3}c - \frac{4}{9}b$ $b > 3c$	$(\cdot,\cdot,\cdot)$	$(M,\cdot,\cdot)$ $w^+ - w > 2c$ $b > 1.5c$	$(M,\cdot,\cdot)$ $w^+ - w > 2c$ $b > 3c$
$j = 7$		$(N, \bar{N}, S)$ $w^+ - w > 3c$ $w^+ - w > \frac{3}{7}b$	(M, M, S) $w^+ - w > 3c$ $b > 3c$	(M, M, S) $w^+ - w > 3c$ $b > 1.5\,c$	$(M, \bar{N}, S)$ $w^+ - w > 3c$ $b > 2c$	$(M, \bar{N}, S)$ $w^+ - w > 3c$ $b > 1.5c$	$(M, \bar{N}, S)$ $w^+ - w > 3c$ $b > 3c$
$j = 8$	$(N, \bar{N}, S)$ $w^+ - w > 3c - 2b$ $w^+ - w > \frac{7}{4}b$	$(N, \bar{N}, S)$ $w^+ - w > 3c$ $w^+ - w > \frac{12}{7}b$	(M, M, S) $w^+ - w > 3c$ $b > 3c$	(M, M, S) $w^+ - w > 3c$ $b > 1.5\,c$	$(\cdot,\cdot, S)$ $w^+ - w > 3c$ $b > c$	$(M,\cdot, S)$ $w^+ - w > 3c$ $b > 1.5c$	$(M,\cdot, S)$ $w^+ - w > 3c$ $b > 3c$

Table A1, conditions for the equilibrium in different versions of game 2, own creation

A5 General equilibrium conditions for two investment alternatives

Scenario 1:

G_1: Internal competition round 1 and round 2

G_1 worst case scenario for investing:

$$v_i(S, S,\cdot,\cdot) > v_i(N, S,\cdot,\cdot)$$

$$\frac{j}{m} * \left(w^+ + \frac{p}{j}b\right) + \left(1 - \frac{j}{m}\right) * w - c > w$$

$$w^+ - w > \frac{m}{j}c - \frac{p}{j}b$$

G_1 best case scenario for not investing

$$v_i(S, N, \bar{S},\cdot) > v_i(N, N, \bar{S},\cdot)$$

$$w^+ + b - c > \frac{j}{m}\left(w^+ + \frac{p}{j}b\right) + \left(1 - \frac{j}{m}\right)w$$

$$w^+ - w > \frac{m}{m-j}c - \frac{m-p}{m-j}b$$

These conditions need to hold to eliminate the alternative $S_{G_1} = \{N\}$

To eliminate $S_{G_1} = \{M\}$ choosing S needs to be beneficial in the best case scenario for M:

$$v_i(S, M,\cdot,\cdot) > v_i(M, M,\cdot,\cdot)$$

$$w^+ - c > \frac{j}{m}\left(w^+ + \frac{p}{j}b\right) + \left(1 - \frac{j}{m}\right)w$$

$$w^+ - w > \frac{p}{m-j}b$$

IF members from G_1 choose to invest, the other individuals will choose not to invest. Hence, under the named conditions $S = (S, N, N)$ will occur.

Scenario 2

G_2: Internal competition round 1

G_2 worst case scenario for investing:

$$v_i\ (S, M, S, \cdot) > v_i(N, M, S, \cdot)$$

$$\frac{j-m}{l}w^+ + \left(1 - \frac{j-m}{l}\right)w - c > w$$

$$w^+ - w > \frac{l}{j-m}\ c$$

G_2 best case scenario for not investing:

$$v_i(\bar{N}, M, N, \bar{S}) > v_i(N, M, N, \bar{S})$$

$$w^+ - c > \frac{j-m}{l}w^+ + \left(1 - \frac{j-m}{l}\right)w$$

$$w^+ - w > \frac{l}{l+m-j}c$$

When these conditions hold $S_{G_2} = \{N\}$ is eliminated. It follows that members of G_3 do not invest.

G_1: Internal competition round 2

If members of G_1 will invest in the following worst case scenario, they will choose M in all other cases as well:

$$v_i(M, M, M, \cdot) > v_i(N, M, M, \cdot)$$

$$w^+ + \frac{p}{m}b - c > w^+$$

$$b > \frac{m}{p}c$$

Given this condition individuals of G_2will choose S. If all conditions are fulfilled $S = (M, S, N)$ will be observed.

Scenario 3

G_2:Internal competition round 1 and round 2

G_2 worst case for investing:

$$v_i(S, \bar{N}, S, \bar{S}) > v_i(N, \bar{N}, S, \bar{S})$$

$$\frac{j-m}{l}\left(w^+ + \frac{p-m}{(j-m)}b\right) + \left(1 - \frac{j-m}{l}\right)w - c > w$$

$$w^+ - w > \frac{l}{j-m}c - \frac{p-m}{j-m}b$$

G_2 best case for not investing:

$$v_i(\bar{N}, M, N, \bar{S}) > v_i(N, M, N, \bar{S})$$

$$w^+ + b - c > \frac{j-m}{l}(\left(w^+ + \frac{p-m}{(j-m)}b\right) + \left(1 - \frac{j-m}{l}\right)w$$

$$w^+ - w > \frac{l}{l+m-j}c - \frac{l+m-p}{l+m-j}b$$

These conditions eliminate $S_{G_2} = \{N\}$. It follows that $S_{G_3} = \{N\}$

To eliminate strategy $S_{G_2} = \{M\}$ as well it needs to be beneficial for individuals of G_2 to choose S in the best case scenario for strategy M:

$$v_i(S, S, M, \cdot) > v_i(M, S, M, \cdot)$$

$$w^+ - c > \frac{j-m}{l}\left(w^+ + \frac{p}{j}b\right) + \left(1 - \frac{j-m}{l}\right)w$$

$$w^+ - w > \frac{(j-m)p}{(l+m-j)l}b$$

Members of G_1 will choose to choose M, when it is beneficial even in the case that favours no investment the most:

$$v_i(M, N, M, \cdot) > v_i(N, N, M, \cdot)$$

$$w^+ + b - c > w^+ + \frac{p+m-j}{m}b$$

$$b > \frac{m}{j-p}c$$

When these condition hold, $S = (\bar{N}, S, N)$ will be observed.

Scenario 4:

G_3: Internal competition round 1

G_3 worst case for investing:

$$v_i(S, \cdot, \bar{N}, S) > v_i(S, \cdot, \bar{N}, S)$$

$$\frac{j-m-l}{n-m-l}w^+ + \left(1 - \frac{j-m-l}{n-m-l}\right)w - c > w$$

$$w^+ - w > \frac{n-m-l}{j-m-l}c$$

G_3 best case for not investing:

$$v_i(S, \cdot, \cdot, N) > v_i(N, \cdot, \cdot, N)$$

$$w^+ - c > \frac{j-m-l}{n-m-l}w^+ + \left(1 - \frac{j-m-l}{n-m-l}\right)w$$

$$w^+ - w > \frac{n-m-l}{n-j}c$$

G_2: External competition

When $S_{-iG_2} = \{\bar{N}\}$

$$v_i(S,\bar{N},S,S,) > (N,\bar{N},S,S)$$

$$w^+ - c > \frac{j-m-(l-1)}{n-m-(l-1)}w^+ + \left(1 - \frac{j-m-(l-1)}{n-m-(l-1)}\right)w$$

$$w^+ - w > \frac{n+1-m-l}{n-j}c$$

When $S_{-iG_2} = \{N\}$

$$v_i(S,\bar{N},N,S) > v_i(N,\bar{N},N,S)$$

$$w^+ - c > \frac{j-m}{n-m}w^+ + \left(1 - \frac{j-m}{n-m}\right)w$$

$$w^+ - w > \frac{n-m}{n-j}c$$

When the left condition holds but the on the right does not, it depends on what individuals of G_2 believe the other group members will do. If the condition on the right holds all group members will choose to invest.

G_1: Internal competition 2

The following condition must hold so that players of G_1 invests:

$$v_i(M,M,S,S) > v_i(N,M,S,S)$$

$$w^+ + \frac{p}{m}b - c > w^+$$

$$b > \frac{m}{p}c$$

If these conditions hold $S = (M,\bar{N},S)$ will be observed.

Scenario 5:

G_3: Internal competition round 1

G_3 worst case for investing:

$$v_i(S,\cdot,\bar{N},S) > v_i(S,\cdot,\bar{N},S)$$

$$\frac{j-m-l}{n-m-l}w^+ + \left(1 - \frac{j-m-l}{n-m-l}\right)w - c > w$$

$$w^+ - w > \frac{n-m-l}{j-m-l}c$$

G_3 best case for not investing:

$$v_i(S,\cdot,\cdot,N) > v_i(N,\cdot,\cdot,N)$$

$$w^+ - c > \frac{j-m-l}{n-m-l}w^+ + \left(1 - \frac{j-m-l}{n-m-l}\right)w$$

$$w^+ - w > \frac{n-m-l}{n-j}c$$

G_2 worst case for investing:

$$v_i(M, M, M, S) > v_i(N, M, M, S)$$

$$w^+ + \frac{p-m}{l}b - c > \frac{j-m-(j-1)}{n-m-(l-1)}w^+ + (1 - \frac{j-m-(j-1)}{n-m-(l-1)}w$$

$$w^+ - w > \frac{n-m-(l-1)}{n-j}c - \frac{n-m-(l-1)}{n-j} * \frac{p-m}{l}b$$

G_2 best case for not investing:

$$v_i(M,\cdot, N, S) > v_i(N,\cdot, N, S)$$

$$w^+ + b - c > \frac{j-m}{n-m}\left(w^+ + \frac{p-m}{j-m}b\right) + \left(1 - \frac{j-m}{n-m}\right)w$$

$$w^+ - w > \frac{n-m}{n-j}c - \frac{n-p}{n-j}b$$

The last two conditions are included in those for G_3 when

$$b > \frac{l}{n-p}$$

Investing is the optimal choice for individuals of G_1 if the following holds:

$$v_i(M, N, M, S,) > (N, N, M, S)$$

$$w^+ + b - c > w^+ + \frac{(p-l)}{m}b$$

$$b > \frac{m}{m+l-p}c$$

When these assumptions hold $S = (M, M, S)$ will be observed.

Scenario 6:

G3: Internal competition round 1 and round 2

G_3 worst case for investing

$$v_i(S,\cdot, \overline{N}, S) > v_i(N,\cdot, \overline{N}, S)$$

$$\frac{j-m-l}{n-m-l}\left(w^+ + \frac{p-m-l}{j-m-l}b\right) + \left(1 - \frac{j-m-l}{n-m-l}\right)w - c > w$$

$$w^+ - w > \frac{n-m-l}{j-m-l}c - \frac{p-m-l}{j-m-l}b$$

G_3 best case for not investing:

$$v_i(S,\cdot, \overline{N}, N) > v_i(N,\cdot, \overline{N}, N)$$

$$w^+ + b - c > \frac{j-m-l}{n-m-l}\left(w^+ + \frac{p-m-l}{j-m-l}b\right) + \left(1 - \frac{j-m-l}{n-m-l}\right)w$$

$$w^+ - w > \frac{n-m-l}{n-j}c - \frac{n-p}{n-j}b$$

If these condition hold $S_{G_3} = (N)$ is eliminated.

For $S_{G_3} = (S)$ the following must hold:

$$v_i(S, N, S, M) > (M, N, S, M)$$

$$w^+ - c > \frac{j-m-l}{n-m-l}\left(w^+ + \frac{p}{j}b\right) + \left(1 - \frac{j-m-l}{n-m-l}\right)w - c$$

$$w^+ - w > \frac{p * (j-m-l)}{j(n-j)}b$$

For G_2 it is beneficial to invest if investing in the case that favours non-investment the most still presents the better option when taking into account the choices of individuals from G_3:

$$v_i(\overline{N}, \cdot, N, S) > v_i(N, \cdot, N, S)$$

$$w^+ + b - c > \frac{j-m}{n-m}\left(w^+ + \frac{p-m}{j-m}b\right) + \left(1 - \frac{j-m}{n-m}\right)w$$

$$w^+ - w > \frac{n-m}{n-j}c - \frac{n-p}{n-j}b$$

If these conditions hold $S = (N, \overline{N}, S)$ can be observed.