LCERPA Working paper No. 2018-9

May 2018

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Abstract

Cognitive impairment has a detrimental influence on the decision-making capabilities of older people. This study investigates the ways in which the time preferences of older adults with mild cognitive impairment (MCI) are influenced by their executive cognitive abilities. Within the framework of this study, older adults underwent a cognitive evaluation using a computerized cognitive assessment battery and then responded to a questionnaire eliciting their preferences for changing amounts of money and time periods. We found that those individuals with better executive cognitive abilities displayed a lower rate of subjective discounting. This study advances our understanding of economic decision-making in old age, especially as influenced by cognitive decline. We hope that our findings will serve as a catalyst in the construction of financial tools relevant to the growing population of older people in society, and thus help to alleviate negative phenomena resulting in older individuals being subjected to fraud and discrimination.

Keywords: mild cognitive impairment, experimental economics, time preferences, financial decision-making, executive functions, old age.

Introduction

Population aging has a direct influence on economic factors, such as economic growth, labor relations, the workforce and its constituents, and welfare and health budgets (Kinsella and Velkoff, 2001). As a manifestation of ageism, people of older chronological age are often regarded as weak and dependent (Doron, 2013), resulting in abuse and discrimination. Older persons are often targeted for financial fraud, especially those with cognitive impairment affecting their decision-making capabilities (Hafemeister, 2002; Johnson, 2004; Klaus, 2005). Older people are often perceived as “easy prey”, partly due to their failing cognition (Friedman, 1992). This study aims to advance our understanding of financial decision-making in old age, especially as influenced by cognitive decline. Our study investigates the ways in which the time preferences of older adults with mild cognitive impairment (MCI) are influenced by their executive cognitive abilities.

Cognitive function and decision-making in older age

Aging is frequently accompanied by a decline in cognitive abilities, resulting in forgetfulness, a reduction in the ability to focus and concentrate, and impaired problem-solving ability (Fotenos et al., 2005, Allen et al., 2005). This may lead to difficulties, such as limitations in performing familiar tasks and learning new skills, impairments in perception and orientation, and an associated anxiety resulting from losing these capacities (Bosworth et al., 1999; Ofstedal et al., 1999; Rahkonen et al., 2001; McNeal et al., 2001). Visual and hearing impairments may further influence age-related changes in the brain and aggravate the decline in memory (Hultsch, Herzog & Dixon, 1990). Older adults often show deficits in a variety of tasks involving cued memory recall and associative memory (Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000; Kausler, 1994).

Executive functions are important for the integration and regulation of other cognitive activities, and they play a central role in an individual’s ability to plan and solve problems. An accepted analogy is that of a conductor of an orchestra who selects which players to bring to prominence and when. While he is responsible for coordinating the musicians, he does not actively play the music. Using this analogy, executive functions are not measured directly, but rather by measuring the functions for which they are responsible. Moreover, executive functions cannot be accurately evaluated based on an isolated behavior, but rather by assessing a wide array of functions. Executive functions are responsible for planning, information processing, and aspects of inhibition and, in certain contexts, for time perception. All of these factors play a role in intertemporal decision-making.

Several studies point to an association between performance of mathematical tasks and executive functions (e.g., Van der Ven, 2012; Bull & Scerif, 2001). Working memory capacity dictates the performance of verbal computational activities and complex written mathematical processes (Geary, 1993). Other studies show that a deterioration of executive cognitive abilities has a negative influence on decision-making (Raz et al., 1998; West, 1996). Moreover, executive functions deteriorate with age (Grieve et al., 2007; Lamar et al., 2002), possibly resulting in an age-related impairment of decision-making abilities. Previous studies have found that advanced age frequently alters one's attitude to economic decision-making (Harle and Sanfey, 2012, Deakin et al., 2004, Castel, 2005), and that cognitive impairment in older age often results in impaired decision-making ability (Band et al. 2002).

Mild Cognitive Impairment (MCI) is frequently an early stage of pathological age-related cognitive decline. It is an acquired condition where cognitive function falls below accepted norms for age and educational level while functional ability remains normal. Those with MCI may have a range of cognitive impairments. MCI affects approximately 15% of the older population, with a high rate of conversion to Alzheimer's disease (AD), especially for those with amnestic MCI (Petersen et al., 2009).

Time Preferences and Subjective Discount Rate (SDR)

Time preferences refer to the evaluation of a specific asset, action or feeling (goods, money, enjoyment, etc.) at an earlier period compared to their appraised value at a later period. There is no absolute definition of an individual's time preferences, which are assessed in a relative fashion. Someone with a preference for the present will tend to forego future utility and instead focus on maintaining his current utility, whereas someone with a high preference for the future will place a greater emphasis on future utility at the expense of present utility.

In economic theory and practice, discounting is the tool used to compare monetary values from one period to another. In order to make an economic comparison between different alternatives, such as cash flow over time, the "discount rate" is used as a common denominator for translating future cash flows into current values. The discount or interest rate reflects "the price of money", representing the price that individuals or organizations expect to be paid to delay consumption, which in effect states the "price" of transferring money from the future to the present. The individual discount rate (subjective discount rate, SDR) is the price an individual will require to postpone consumption from the present to the future. An accepted manner to estimate this rate is by employing questionnaires that offer someone the option of postponing consumption of a given amount from the present to the future and asking what amount would be required to justify this postponement. Comparing the future value against the present value gives an estimate of the subjective discount rate (Laibson, 1997; Read, 2001; Benzion et al., 2004; Mahajna et al., 2008; Gringon, 2009).

Subjective discount rates vary from individual to individual and are dependent upon factors such as personality traits. Psychological theory refers to “delayed gratification” in this context. It is reasonable to assume that individuals with a low ability to delay gratification will find difficulty in waiting to receive money and thus will demand a larger amount for agreeing to postpone their receipt of the money, as compared to those with a higher delayed gratification threshold. In general, someone who prefers present over future consumption will be characterized by a higher discount rate than a more “patient” person who is willing to postpone a portion of his consumption to the future. Measuring the factors that influence the SDR and mapping the correlations and the elements that influence its size are important for enhancing knowledge about time preferences. This allows for a better understanding of consumption, saving and investment behaviors, and has implications for improving individual and social welfare (Laibson,1997; Read, 2001; Benzion et al., 2004; Mahajna et al., 2008; Gringon, 2009).

The effect of aging on time preferences

Age-related changes may alter economic preferences over the course of one’s lifetime (Trostel and Taylor, 2001). An awareness of one’s limited lifespan is a fundamental human characteristic playing an important role in motivation (Carstensen et al., 1999). This also influences an individual’s time preferences in the financial context. Thus, for example, a young adult who estimates that he will live for many years has a greater motivation to save than an older individual who estimates that a more limited life expectancy. In addition, psychological aspects that are characteristic of different age groups are likely to influence time preferences.

The influence of age on time preferences has been evaluated in several studies. Green et al. (1994) found that the discount rate was highest among adolescents and lowest among older people. In contrast, Read & Read (2004) found that the highest discount rate was observed among the elderly, followed by young adults, with the lowest being middle-aged adults. These differences were even stronger with longer periods of delay (delay of 3 to 10 years).

The effect of risk preferences on time preferences

An additional variable that may influence individuals' time preferences is risk preferences, which reflect the tendency of a person to refrain from risky behavior. Apart from the individual's risk preferences, which are a personality characteristic, risk-related decisions are also influenced by the individual's subjective risk perceptions (Brockhaus, 1980; Rabin, 2000; Riley & Chow, 1992; Tochkov, 2009). Risk-averse individuals will have more difficulty accepting uncertainty related to future income, which may lead to a higher SDR and require a higher compensation to delay consumption for future payment (Stevenson, 1986). In a trial that combined lotteries as a measure of degree of risk aversion and a questionnaire related to payment delay, Anderhub et al. (2001) found a positive association between the degree of risk aversion and SDR. In a related study, Andersen et al. (2008) also included a questionnaire relating to lotteries and time preferences and found a low positive correlation between risk aversion and SDR. In choosing between lotteries with different amounts and payment dates, Ida and Goto (2009) found that smokers exhibited more impatience and a greater tendency toward risk-taking than non-smokers. The study showed a negative correlation between risk aversion and SDR.

Morbidity, mortality and time preferences

Time and risk preferences may also be influenced by aspects of morbidity and mortality. Chao et al. (2009) investigated the relationship between physical health, subjective expectations relating to survival, and the SDR in South Africa where mortality at mid-age is higher than in other developed countries due to the high prevalence of infection with human immunodeficiency virus (HIV). The study found a U-shaped correlation between physical health and SDR, such that either very healthy or very sick people had higher SDR than people of average health. A similar relationship was found between survival probability and SDR, with respondents who estimated that they had either low or high survival probabilities had a higher SDR than those who estimated their survival probability to be average. Age was not a strong predictor of expected survival and health, and consequently not of SDR (Chao et al. 2009).

Milenkova et al. (2011) investigated the influence of Parkinson's disease on intertemporal preferences. They found that the decisions of those patients with Parkinson's disease who did not display impulse control disorders tended to differ from those of healthy individuals. Regarding intertemporal monetary choice, the patient group showed significantly higher discount rates than the control group.

As described above, cognitive ability and morbidity are important factors in age-related aspects of the decision-making process. The current study examines the influence of cognitive function on the time preferences of older people with mild cognitive impairment. We evaluated the association between the cognitive functions of older people with MCI and their SDR.

Findings from a preliminary study performed at the Beer-Sheva Mental Health Center provided a reasonable foundation to assume that MCI may influence time preferences and the way in which an individual regards the value of money and the discount rate.

We aimed to determine whether a gap exists between the SDR of cognitively healthy older people and that of older people with MCI. We postulated that those with cognitive impairment will require a statistically significantly higher price than cognitively healthy people to delay consumption. Also, we predicted a direct relationship between cognitive functions, particularly executive function, and the strength of time preferences, and that the awareness of morbidity will have an influence on SDR. We believe that our study furthers our understanding of the perception of the value of money by older people, particularly those with cognitive impairment resulting from MCI.

Materials and Methods

Participants

The study population included subjects aged 60 years and older diagnosed with MCI, and a control group of similarly aged individuals whose cognitive function was within normal limits. All subjects underwent a comprehensive clinical evaluation and the Neurotrax computerized cognitive assessment (NeuroTrax Corp., Modiin, Israel) at the Memory Clinic of the Beer-Sheva Mental Health Center. The NeuroTrax cognitive assessment battery has been validated for evaluating older people with MCI (Dwolatzky et al., 2003). The diagnosis of MCI was based on clinical criteria (Petersen, 2009). In addition, subjects completed a questionnaire relating to time preferences, similar to those used in previous studies (e.g., Laibson,1997; Read, 2001; Benzion et al., 2004; Mahajna et al., 2008; Gringon, 2009). The subjects were requested to choose between sums of money at the present time, or at various time periods in the future. The questionnaire was adapted to the needs of the study population, with an emphasis on a user-friendly format. Patients were asked about the postponement of sums of 200 New Israeli Shekels (NIS) (equivalent to about $50 USD) and 2,000 NIS (equivalent to about $500 USD) for a period of either one week, one month, two months, six months or one year. The two sums were selected to represent a small but not insignificant amount of money (200 NIS) as well as a substantial sum for most participants (2,000 NIS). At the time of the study, the mean net per capita income for older people in Israel was 4,756[1] NIS per month (about $1200).

Data analysis

A number of univariate and multivariate models were constructed to determine which of the independent variables affected the individuals' SDR. For each sum and time duration a separate model was evaluated. The independent variables used in the models were: global cognitive score, executive function index, income, gender, and a dummy variable for group classification (healthy and sick). The education and age variables are standardized within the Neurotax™ score and were thus not included in our models.

The dependent variables in this study were SDR for different sums and time periods. The ten possible time periods presented to subjects for postponing the receipt of money were: postponement for one week, one month, two months, six months, and a year, each for the amounts of 200 NIS and 2000 NIS, respectively.

For the computation of descriptive statistics and testing of the model using linear regression analysis, the SDR was calculated as follows[2]:

$$r = \left(\left(\frac{F_T}{P}\right) - 1\right)$$

The SDR was calculated on an annual basis. For example, if the individual required a payment of ₪210 to postpone a payment of ₪200 for one week, his maximum SDR would be 5% for a week, and the annual rate calculated using simple interest for 52 weeks would be 260%.

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[1] Source: The Elderly in Israel - Statistical Abstract 2011, Brookdale Institute, Jerusalem.

[2] $\mathbf{F_T}$ – the future sum requested by the individual to delay consumption until after time-period **T** (in the future); **P** is the value of sum requested in the present; and **r** is the SDR needed for a **T** time-period delay.

Since we used a closed questionnaire, any amount chosen in the questionnaire represents a range of discount rates within which individual time preferences are located.

A non-linear, hyperbolic model was also employed for the estimation of the abatement function, describing the change in value between present and future amounts of money, in the following manner:

$$P = F * \frac{1}{(1 + rt)}$$

The hyperbolic discount function was used in accordance with Laibson (1997) who describes the empirical advantages of this function to characterize individuals' time preferences.

The variable MCI was defined as a dichotomous variable that differentiates between individuals determined to have a diagnosis of MCI (value of 1) and those who were cognitively healthy (value of 0). It was expected that patients with MCI would have stronger time preferences for the present. Since MCI constitutes a diagnosis that can result from a variety of impairments in cognitive abilities, we expected that direct variables would better explain an individual's decision-making process.

Interviews with psychiatrists as part of the preliminary study at the Beer Sheva Mental Health Center gave us the impression that MCI does not carry with it a high awareness of morbidity, in contrast to patients with terminal illness. In the opinion of the clinical team, people suffering from this impairment do not feel that their lives are about to end or that they suffer from a terminal illness, despite the literature predicting that the diagnosis of MCI is associated with a higher than average likelihood of developing AD. On the other hand, most patients assessed in the memory clinic request an evaluation because of their own or others' complaints of deteriorating function, mainly in memory. In a society with high awareness of AD, it is likely that there is a certain level of awareness of morbidity. To evaluate the patients' feelings regarding their health status, we added a variable to the self-health assessment, which will be described later.

The NeuroTrax global assessment score combines the results of all the cognitive tests performed to produce a weighted score corrected for the individual's age and educational level and reflects an overall measure of cognitive ability. As described above, MCI expresses the deterioration in various cognitive abilities. Thus, for example, a person with memory impairment and a person with executive function impairment may both be defined as suffering from MCI, despite having different impairments.

Time preferences are a personal preference and we found no indication in the literature as to how or in which direction it is influenced by cognitive abilities. We postulate that individuals with better cognitive abilities would tend to be more patient and thus have lower subjective discount rates.

The Executive Function Index constitutes a combination of the results of three tests performed within the NeuroTrax battery: Go-No-Go, Stroop, and the Catch Game. Given the importance of executive functions to the decision-making process, we evaluated the correlation of this variable with the individual's time preferences.

The gender variable is dichotomous, receiving the value of 1 for women and 0 for men. According to previous studies, women tend to have a stronger future preference than men, namely, they are characterized by lower discount rate (see, e.g., Dittrich & Leipold, 2014).

The Self-health assessment variable relates to subjects' self-assessment of their current and near-future health status expectations. This variable was used to estimate awareness of morbidity among those with MCI and their expectations regarding their future health. These are categorical variables comprised of four questions, each with 5 levels of response. These questions were weighted to form a single index (Self-health assessment index). The index was a mean of the ranked answers to all questions. The index was based upon previous studies employing this type of questionnaire (Vander et al., 2014; Ware, 1999). It is reasonable to assume that subjects with MCI would have a greater awareness of morbidity than the control group, with concern and uncertainty regarding the future. We also included a question relating to the individual's self-assessment of near-future health status.

The variable estimating the subject's risk preference is a continuous variable based on the following question (see Booij & van Praag 2009; Lahav et al., 2011):

Assume that we are offering to sell you a lottery ticket. During the lottery, a coin will be tossed. If the coin lands on "heads" you will win 2,000 NIS and if it lands on "tails", you will win nothing (0 NIS). How much would you be willing to pay for this lottery ticket?

Answer: I would be willing to pay ____ NIS to participate in this lottery.

The more the individual was willing to pay for the lottery ticket described, the higher the willingness to take risks.

Results

Descriptive results

Our subjects consist of a sample of referrals aged 60 years and older evaluated at the memory clinic of the Beer Sheva Mental Health Center, as well as asymptomatic volunteers of a similar age residing in the community. The sample included 101 participants, 66 with and 35 without MCI ; 58.4% were women. The demographic characteristics of the sample population are shown in Table 1.

-Table 1 here-

The patient population was slightly older than the cognitively healthy population, a difference that was found to be statistically significant in the variance analysis (p=0.005)[3]. This finding is not surprising, since the chance of developing MCI increases with age. There was no statistically significant difference in the number of children between the two groups. The patient population was characterized by a higher rate of widowhood, which is common in people of older age. In general, it was found that the patients tended to have lower incomes, as can be seen in Graph 1.

-Graph 1 here-

Graph 2 shows the educational level of the respondents. It is not possible to identify a uniform trend in these data.

-Graph 2 here-

Tables 2 and 3 show the results for individuals' SDR[4] calculated according to different postponement time periods (one week, one month, two months, six months and one year). The discount rate is presented in annual terms.

-Table 2 here-

-Table 3 here-

The discount rate required is higher amongst those with MCI for both of the postponed sums and for all time periods. In addition, and consistent with Thaler (1981), the required discount rate (in annual terms) is inversely related to the length of time to be waited and the size of the payment (average of 19.98 for postponing 2,000 NIS for one week compared to 16.03 for postponing 200 NIS for the same period, 1.41 for postponing 200 NIS compared to average of 1.06

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[3] The cognitive test results corrected for age and education level.

[4] Calculated as explained in section on SDR: $r = \left(\left(\frac{F}{P}\right) - 1\right)\left(\frac{12}{t}\right)$.

for postponing 2,000 NIS for one year). These trends are illustrated in the Graph 3. For all postponement durations, patients with MCI are characterized by higher SDRs.

A series of cognitive tests were included in the clinical assessment of the patients and controls, including executive functions, visual perception, memory and attention. In order to examine the significance of the scores and the test performance differences between cognitively healthy individuals and patients, linear regressions were performed, with the response variable being the relevant cognitive test result. Table 4 reports the results. The constant term can be interpreted as the mean score for the cognitively health individuals, while the estimate of coefficient on the MCI dummy variable reflects the difference in the patients.

-Table 4 here-

The cognitive abilities of those with MCI differed significantly from those of the controls according to all measures. The mean global cognitive score in the cognitively healthy group was 102.12 ± 7.51 and 93.59 ± 10.95 in the patient group. As demonstrated in the regression analysis in Table 4, there is a statistically significant difference in higher functions between the two groups. The individuals' average executive functions score was 102.53 ±9.45 in controls and 95.43 ±12.78 in patients. There was a statistically significant difference in the executive function level between the two groups. It is evident that cognitively healthy individuals are generally characterized by better results, but the magnitudes of the differences are not uniform across functions. This probably arises from the fact that the various abilities are impaired differently in individuals. The executive function score and global score were highly correlated (0.8511). According to the literature, executive functions have an important influence upon decision-making. Regressions analyses examining the influence of other cognitive measures on intertemporal choices reinforced the assumption that the significant measures explaining individuals' intertemporal decisions are the global cognitive score and the executive functions score.

In evaluating the risk preference score we found that those with MCI tended to offer higher sums for the lottery, thereby reflecting a greater risk preference (Table 5). The difference between the groups is borderline statistically significant ($p=0.06$).

-Table 5 here-

The self-health assessment score showed that the cognitively healthy group tended to value its health slightly more than the patient group (mean score for controls 3.94 versus 3.42 for MCI), as can be seen in Table 6. Variance analysis found a highly significant difference between the groups ($p<0.01$).

-Table 6 here-

Econometric models and processing of the findings

Several econometric models were constructed to identify variables influencing subjects' SDR. The analysis was performed in two stages, first using a linear model and then using a hyperbolic model. The different variables were analyzed to find the model that best explains the intertemporal choices of individuals in the sample.

Linear model analysis

The data were analyzed using an OLS model of all time groups (one week, one month, two months, six months and one year) and sums (200 NIS, 2000 NIS). We found that the variables best explaining these decisions are: executive functions; existence of MCI or lack thereof; and gender. The econometric analysis is presented in Table 7 and Table 8.

-Table 7 here-

-Table 8 here-

In the first stage (model 1), one response variable is included, namely whether the individual is cognitively healthy or has MCI. The second model (model 2), controls for the executive functions assessment. The third model (model 3) includes the subject's gender.

MCI alone did not explain individuals' SDR when requested to postpone payment for periods of under one year. The interpretation of this finding is that there is no evidence that within short time ranges the existence of MCI affects those individuals with the condition relative to those who do not have MCI. In contrast, for long time ranges postponement of one year, individuals with MCI differ significantly from those without MCI as they require greater compensation for postponement for both sums tested. We found that the additional interest rate required by patients to postpone the sums for one year is statistically significantly higher (0.56 for 2000 NIS and 0.47 for 200 NIS, in annual terms). The implication is that for postponement of 2000 NIS the additional rate required is higher than that for postponement of 200 NIS. Accordingly, those with MCI required a mean sum of 1200 NIS more than controls to postpone 2000 NIS for one year and 94 NIS more than controls to postpone 200 NIS for a similar period.

With the addition of executive functions and gender variables to the model, the MCI variable remains statistically significant for the postponement of one year. Since the other cognitive abilities examined were unable to improve the level of explanation of the intertemporal choices relative to executive functions, it appears that executive functions embody the main influence in question and it is therefore likely that the MCI variable also embodies within it aspects of morbidity and mortality awareness. The results in this context, namely, the significance of the morbidity variable only for postponement for the period of one year, can be explained as the influence of such awareness. Thus, the additional interest required by healthy participants may result from these individuals' concern that their illness will impair either their life expectancy within the range of one year or their ability to enjoy their money in the long term.

An examination of the differences between the groups, those with MCI and the cognitively healthy group, shows that individuals who would be diagnosed[5] with MCI indeed reported significantly worse mean health status according to the health score assessed ($p<0.001$). However, there was no statistical significant difference between the groups in the evaluation of the possible deterioration of their health in the near future ($p=0.107$).

The fact that individuals with MCI did not report an expected future deterioration in their health status is somewhat surprising. It is expected that those with MCI are aware that they have cognitive symptoms, which is why they turned to the clinic for assessment. Therefore, together with the expectation that their self-health assessment would be relatively lower than that of healthy subjects, we also expected it was likely they would estimate a future deterioration in their health. Meir and Rol (2012) performed a study that examined and ranked the degree of issues concerning older people in Israel. They found that about 73% have a high level of concern regarding their future health status and 68% are concerned about becoming dependent on others. In addition, older people have a high awareness of AD and this constitutes one of their main health concerns (Graham et al., 1997). It is therefore logical to expect some degree of morbidity awareness, certainly in the long term. It is possible that those with MCI will take their illness into consideration when making decisions over a much longer horizon (e.g., more than a year, which was not addressed in our study).

The executive functions score was entered into models 2 and 3. This variable was significant for all combinations of amounts and postponement times, except for the group with

[5]Note well that during the completion of the questionnaires and the medical diagnosis for the study, individuals did not know their diagnosis.

postponement of 200 NIS for one week. A higher score in executive functions correlates with a lower required SDR. The discount rate reduction in yearly terms becomes smaller with an increase in the postponement time. However, the differences between reduction in the different amounts are not especially large (for postponement of 200 NIS, 0.25 reduction per month and 0.03 per year for every index point; for postponement of 2000 NIS, 0.26 less per week and 0.02 less per year for every index point in model 3; the results in model 2 are similar). In the linear model, the first option to appear on the questionnaire (i.e., the postponement of 200 NIS for one week) also involved the smallest payment and shortest time period. Results for this option are different from the other nine options. Notably the estimated executive functions level does not explain SDR to a statistically significant degree. There are two possible explanations for this result. The first is that because the sum in question is small and the time postponement is short, individuals do not attach sufficient importance to the choice. The second is that because this is the first question in the questionnaire, it appears that many respondents answered it in a more superficial fashion than the subsequent questions.

The data analyses showed that executive functions index scores show 85.11% correlation with the global cognitive score. On examining the measures comprising the global score, executive functions were found to best explain individuals' intertemporal choices, both when compared to other cognitive measures and relative to the global score. Overall, the models presented show that, except for the case of one-week postponement of 200 NIS, executive functions explain individuals' SDR with a high degree of statistical significance. We thus included the executive functions score as a variable in the model instead of the global score, since using the global score includes other confounding variables that reduce the precision of the model.

Gender was added as a variable in model 3. For periods of six months and greater, women tend to require higher compensation for postponement. The increase in discount rate is greater for six-months postponement relative to one-year postponement and lower for postponement of 2000 NIS versus postponement of 200 NIS (1.41 and 0.85 for postponement of 200 NIS for six months and for one year, respectively, and 0.88 and 0.51 for postponement of 2000 NIS for six months and one year respectively). This result differs from those studies asserting that men tend to be less patient (Dittrich & Leipold, 2014). Examining the interactions between the MCI variable, executive functions and gender did not yield statistically significant results. A possible explanation for this finding may be the fact that our older population differed from those investigated in other studies of intertemporal choices and gender – a topic worthy of future research.

The addition of the self-reported income variable did not contribute to the model, being only weakly significant and only for some of the time periods. A possible explanation for this is the relationship between executive functions and income level. Executive functions level constitutes an explanatory variable for the income level, with borderline statistical significance ($p=0.06$). Running a test with the income variable as the single variable to explain subjective discount rates showed statistical significance, to different degrees, for both the amounts and time periods, except for postponement of one week (for both amounts).

The risk-preference measure (i.e., willingness to pay for a given lottery ticket), was not found statistically significant as an explanation of the discount rate and does not contribute to the model. Notwithstanding and consistent with the literature (see, e.g., Jianakoplos & Bernasek, 1998), [6] women were found to be more risk averse than men. In addition, minimal statistically

[6] There are also studies that conclude that these differences are relatively limited, and non-existent in some cases (Schubert et al., 1999)

significant differences in risk preferences were found between MCI patients and individuals without MCI.

-Table 9 here-

As can be seen in models 1 through 5, the MCI variable has moderate-low statistical significance, and has a positive coefficient, that is, patients with MCI tend to bid statistically significantly higher amounts for the offered lottery ticket compared to healthy individuals (ranging from 97.25 NIS more in model 1 to 47.89 NIS more in model 2), meaning they tend to take greater risks. The gender variable also shows moderate statistical significance, with a negative coefficient, indicating women tend to bid lower amounts (ranging from 137.61 in model 2 to 123.48 in model 5), meaning they take less risk. Surprisingly, the income and executive functions variables are not statistically significant in this context. This result is surprising, especially regarding the executive functions variable that shows no statistical significance both in the models presented and as a single explanatory variable.

The questionnaire included a number of additional control variables that we hypothesized might influence individuals' intertemporal decision making (namely, degree of religious observance, birthplace, being a Holocaust survivor). No statistically significant association was found between these variables and individuals' intertemporal decision-making.

Discount Function Estimation – Hyperbolic Model

The study's assumption is that the required discount rate is a function of the individual's distinguishing characteristics, in the following manner:

$$sdr = f(executive\ functions, amount, mci, gender \ldots.)$$

Empirical studies found that the discount rate is not constant, but decreases over time. That is, the cost of delaying a reward exhibits decreasing returns to scale (Ainslie, 1991). Accordingly, studies in behavioral economics assume that hyperbolic functions better simulate individuals' discounting characteristics. Therefore, for the purpose of this study, the abatement rate, D(r,t) was calculated using the hyperbolic formula. The regression equation is described as follows:

$$P=F_T * D(r,t) = F_T * \frac{1}{(1+t*r)} = F_T * \frac{1}{(1+t(k+a*variable1+b*variable2+c*variable3.....))}$$

Where $\mathbf{F_T}$ – the future sum requested by the individual in order to delay consumption until after time-period **T** (in the future); **P** is the current value of the postponed payment; and **r** is the SDR needed for a **T** time-period delay.

The personal or subjective discount rate (SDR) is represented as follows:

$$SDR = r = (k + a * variable1 + b * variable2 + c * variable3 \ldots..)$$

With this model, we are, in effect, estimating the discount rate (r) corresponding to the population tested that characterizes its behavior according to the responses participants gave to the questions about postponing different payments for various time periods. The data analysis in this section is done using all of the observations, that is, all ten answers (five periods for two amounts) were weighed in the regression, taking into account possible dependence between the observations of the same subjects.[7] It is important to note that the abatement rate is affected by the SDR, namely, the lower the SDR, the higher the future value (lower abatement rate).

To estimate the influence of the measured variables on the discount rate, other variables that we estimate as having an influence on the discount rate were also considered in the function. These were incorporated in the formula in the following manner:

$$D(r,t) = \frac{1}{(1+t(k+a*executivescore+b*amount+c*mci.....))},$$

[7] Using a cluster-corrected standard errors model.

where *t* is the period of postponement (in days). Thus, the discount rate, *r,* is a linear combination of the tested variables. The *k parameter is the constant in the linear equation, and the estimated parameters a, b, c, etc. are the weights placed on* the variables. For example, a negative value of *a* indicates that a higher executive functions index score is associated with a lower discount rate.

In addition to the simple model, we tested multi-variate models whilst combining the control variables that were added to the model. The results of the analysis described are shown in Table 10.

-Table 10 here-

The coefficient k has a positive sign, consistent with the theory, and has a high degree of statistical significance in all of the models. Also, the coefficients for the results of the executive functions estimate explain the discount rate with a high degree of statistical significance in all models. As predicted, the coefficient for this variable is negative. The meaning of a negative result for the executive functions coefficient is that every increase of one point in the estimated index score will reduce the discount rate (when the relevant time product is taken into account). Therefore, people with higher executive functions will request a smaller sum, which is consistent with our hypotheses.

The coefficient for the postponed amount variable (200 or 2000) is also highly statistically significant across all the models and is negative, corresponding to the literature. The meaning is that individuals request a lower discount rate to postpone a larger sum, relative to their request for postponement of smaller amounts.

The income variable was incorporated in model 5, and its coefficient was not statistically significant. The explanation of this is apparently similar to the explanation given in the linear model; that is, high correlation between income and other variables, particularly the executive functions level.

Incorporating the MCI morbidity variable showed moderate statistical significance in the models in which it was incorporated (4, 5). This result reinforces the finding from the linear model that MCI morbidity has an influence on individuals' choices, apparently due to aspects of morbidity awareness, as was explained in the linear model. The coefficient is positive in this model as well; that is, sick individuals tend to require higher discount rates.

The coefficient for gender was not significantly different from zero in this model (6), in contrast to much of the literature and our result from the linear model.

The discount function estimates for individuals with varying executive function scores can be seen in Graph 4 (68 is the minimum score recorded and 125 the maximum).

$$D(r,t) = \frac{1}{(1 + t(k + a * executivescore))}$$

-Graph 4 here-

As was expected, also when the function was estimated in this manner, individuals who received a higher score in the executive functions estimate (those individuals whose executive functions were estimated to be better) are characterized by a flatter discount function and their discount rates are lower. This means that they require lower compensation for delayed consumption (i.e., more future-oriented preferences). The adjusted r^2 for the models is relatively high, ranging from 0.6436 in model 1 to 0.6857 in model 6.

Discussion

We found that changes in executive function in subjects with MCI influenced their subjective time preferences. These findings support the hypothesis that MCI may influence individuals' time preferences as expressed by the SDR. The influence is bifactorial, firstly resulting from a person's awareness of morbidity, and secondly via the impairment of executive functions. The study found the influence of morbidity mainly present in the longer term, namely, in cases of postponement for a year, while the hyperbolic model shows the influence to be more extensive. For all time periods studied, the main influence on intertemporal decisions is via executive functions.

The statistically significant association between executive measures and SDR can help in evaluating the change in cases where abilities are measured at different points in time. We found that low executive functions are associated with high discount rate and present-oriented preferences. While a connection between executive functions and decision-making has been found in the literature, the observed relationship between executive functions and intertemporal preferences constitutes a novel finding. Based on the literature, executive function impairment would be expected to lead to lower quality decision-making, but in a sporadic fashion and not necessarily in a particular direction. Despite this expectation, our study shows that individuals with low level executive functions tend to require high discount rates. It is possible that this phenomenon results from the fact that individuals try to refrain from decisions that appear to them to be complicated. Individuals with low executive functions see intertemporal time choices as complicated, requiring time perception and the consideration of a number of factors that are non-trivial for them. Therefore, they prefer the simple option, receiving the money today. Therefore, if we force them to choose, they require a high price to accept a future payment. An alternative explanation is that those with low executive functions feel more ill than those with higher executive functions and that the influence of morbidity awareness plays a role; however, we did not find support for this explanation. Low executive function level was not associated with low self-health assessment or a greater expectation of future health deterioration.

The results of this study show that individuals’ financial decision-making is influenced by their health status and their cognitive abilities, which generally decline with increasing age. This finding may be helpful for adaptation of financial and other services for the older population, with consideration and understanding of the special needs of many of the individuals who comprise this population group. The understanding that older people in general, and especially those with cognitive morbidity, tend to display present-oriented financial preferences, may be a basis for further investigating these preferences also in the context of consumption. It may thereby be possible to contend better with the widespread phenomenon of fraud against older people, and to find appropriate mechanisms to protect this population.

This study has several limitations. First, the sample is a convenience sample and the sampled groups are small. In addition, MCI is a heterogeneous group and includes a wide range of impairments. Nevertheless, we hope that our interesting and novel findings will provide the basis for further research in this important field.

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Tables

Table 1: Demographic characteristics

MCI					
Variable	N	Mean	Std. Dev.	Min	Max
Age (Years)	66	75.36	8.43	61.41	93.62
Number of children	66	3.27	1.32	1.00	6.00
Marital Status		Single	Married	Divorced	Widow
	66	1.52%	62.12%	4.55%	31.82%
No MCI					
Age (Years)	35	70.43	7.50	60.61	86.73
Number of children	35	2.97	1.29	0.00	6.00
Marital Status		Single	Married	Divorced	Widow
	35	2.86%	77.14%	0.00%	14.29%
All					
Age (Years)	101	73.65	8.42	60.61	93.62
Number of children	101	3.17	1.31	0.00	6.00
Marital Status		Single	Married	Divorced	Widow
	101	1.98%	67.33%	4.95%	25.74%

Table 2: SDR data, postponement of 200 NIS (about $50)

		Week	Month	Two Months	Six Months	Year
No MCI	Mean	16.92	6.81	4.04	2.04	1.10
	N	35	35	35	34	35
	Std. Deviation	35.59	10.01	5.55	2.09	1.04
MCI	Mean	21.70	7.21	4.56	2.58	1.58
	N	62	65	65	66	66
	Std. Deviation	41.70	10.23	5.68	2.25	1.25
Total	Mean	19.98	7.07	4.38	2.39	1.41
	N	97	100	100	100	101
	Std. Deviation	39.48	10.11	5.61	2.20	1.20

Table 3: SDR values, postponement of 2,000 NIS (about $500)

		Week	Month	Two Months	Six Months	Year
No MCI	Mean	11.07	3.86	2.72	1.27	0.70
	N	34	35	34	35	35
	Std. Deviation	23.36	7.07	4.54	1.84	0.90
MCI	Mean	18.67	6.05	3.48	1.91	1.26
	N	64	65	66	66	66
	Std. Deviation	40.90	10.35	5.05	2.16	1.22
Total	Mean	16.03	5.28	3.22	1.69	1.06
	N	98	100	100	101	101
	Std. Deviation	35.85	9.35	4.87	2.07	1.14

Table 4: Regression data cognitive scores based on NeuroTrax cognitive assessment battery

Variable		Coef.	Std. Err.	p-value	r2
Global score	Cons.	102.12	1.26	0.00	
	MCI	-8.53	1.86	0.00	0.15
Executive functions score	Cons.	102.53	1.59	0.00	
	MCI	-7.11	2.25	0.00	0.08
Memory score	Cons.	99.86	2.38	0.00	
	MCI	-13.32	3.09	0.00	0.15
Attention score	Cons.	100.73	1.78	0.00	
	MCI	-7.68	2.89	0.01	0.05
Visual spatial score	Cons.	105.51	2.60	0.06	
	MCI	-5.98	3.17	0.00	0.04

Table 5: risk preference data

Variable					
MCI	N	Mean	Std.Dev.	Min	Max
Risk preferences (Lottery)	50	136.96	287.09	0.00	1000.00
No MCI					
Risk preferences (Lottery)	31	39.71	57.28	0.00	200.00
All					
Risk preferences (Lottery)	81	99.74	232.33	0.00	1000.00

Table 6: Self-Health Assessment data by groups

MCI					
Variable	N	Mean	Std. Dev.	Min	Max
Self-Health Assessment	51	3.42	0.73	1.75	5.00
No MCI					
Self-Health Assessment	32	3.94	0.69	1.50	5.00
All					
Self-Health Assessment	83	3.62	0.75	1.50	5.00

Table 7: linear model (SDR), 200 NIS

Dependent variable - subjective discount rate.
Postponed Amount: 200 ILS

Postponement period	Week	Week	Week	Month	Month	Month	2 Months	2 Months	2 Months	6 Months	6 Months	6 Months	Year	Year	Year
Constant	16.92***	65.32	51.39	6.81***	33.17***	30.74***	4.04***	20.06***	17.70***	2.04***	8.26***	6.19***	1.10***	4.46***	3.20***
	(5.99)	(40.00)	(43.72)	(1.69)	(9.66)	(11.03)	(0.93)	(5.29)	(5.70)	(0.36)	(1.87)	(2.00)	(0.17)	(1.01)	(1.03)
Patients with MCI (Dummy)	4.78	1.68	3.94	0.40	-1.35	-0.90	0.52	-0.55	-0.09	0.54	0.14	0.53	0.47**	0.26	0.50**
	(8.00)	(8.42)	(8.55)	(2.11)	(2.00)	(1.91)	(1.17)	(1.10)	(1.07)	(0.45)	(0.44)	(0.43)	(0.17)	(0.23)	(0.22)
Executive functions		**-0.47**	**-0.40**		**-0.26*** **	**-0.25** **		**-0.16*** **	**-0.14*** **		**-0.06*** **	**-0.05*** **		**-0.03*** **	**-0.03*** **
		(0.37)	**(0.38)**		**(0.09)**	**(0.098)**		**(0.05)**	**(0.05)**		**(0.017)**	**(0.018)**		**(0.009)**	**(0.009)**
Female (Dummy)			8.41			1.61			1.59			1.41***			0.85***
			(8.28)			(2.07)			(1.08)			(0.41)			(0.22)
R-squared	0.003	0.023	0.033	0.0004	0.088	0.094	0.002	0.108	0.126	0.014	0.120	0.213	0.036	0.141	0.255
Adjusted R-squared	-0.007	0.002	0.001	-0.0098	0.069	0.065	-0.008	0.089	0.098	0.004	0.101	0.188	0.026	0.123	0.232

*** Statistically significant at 1% level
** Statistically significant at 5% level
* Statistically significant at 10% level

Table 8: linear model (SDR), 2000 NIS

Dependent variable - subjective discount rate.
Postponed Amount: 2,000 ILS

Postponement period	Week	Week	Week	Month	Month	Month	2 Months	2 Months	2 Months	6 Months	6 Months	6 Months	Year	Year	Year
Constant	11.07***	100.96**	106.01**	3.86***	30.73***	30.47***	2.72***	16.95***	16.91***	1.27***	6.38***	5.08**	0.70***	3.37***	2.62**
	(3.99)	(38.9)	(43.00)	(1.19)	(9.78)	(10.87)	(0.77)	(5.32)	(5.73)	(0.31)	(1.85)	(2.04)	(0.15)	(1.13)	(1.16)
Patients with MCI (Dummy)	7.60	1.73	0.85	2.18	0.37	0.42	0.76	-0.20	-0.20	0.64	0.30	0.55	0.56***	-0.03*	0.53**
	(6.49)	(5.81)	(5.69)	(1.75)	(1.62)	(1.60)	(0.99)	(0.98)	(0.95)	(0.41)	(0.40)	(0.41)	(0.21)	(0.01)	(0.22)
Executive functions		**-0.88** **	**-0.90** **		**-0.26*** **	**-0.26*** **		**-0.14*** **	**-0.14*** **		**-0.05*** **	**-0.04** **		**0.03** **	**-0.02** **
		(0.37)	**(0.38)**		**(0.09)**	**(0.10)**		**(0.049)**	**(0.051)**		**(0.017)**	**(0.018)**		**(0.01)**	**(0.01)**
Female (Dummy)			-3.34			0.17			0.027			0.88**			0.51**
			(7.84)			(1.95)			(0.97)			(0.40)			(0.22)
R-squared	0.010	0.093	0.095	0.013	0.120	0.120	0.006	0.117	0.117	0.022	0.101	0.142	0.055	0.128	0.172
Adjusted R-squared	-0.0004	0.074	0.066	0.002	0.102	0.093	-0.005	0.098	0.089	0.012	0.083	0.115	0.046	0.110	0.146

*** Statistically significant at 1% level
** Statistically significant at 5% level
* Statistically significant at 10% level

Table 9: Risk preference regressions

Dependent variable - index of risk preferences	(1)	(2)	(3)	(4)	(5)
Constant	39.71***	155.12***	-162.02	24.87	-256.74
	(10.25)	(51.56)	(378.67)	(83.00)	(395.15)
Patients with MCI (Dummy)	97.25**	47.89*	77.07*	57.25*	81.98*
	(41.97)	(26.65)	(45.73)	(33.31)	(48.52)
Female (Dummy)		-137.61**	-131.32**	-129.75**	-123.48**
		(58.03)	(58.08)	(54.49)	(56.21)
Income level				33.00	26.38
				(22.35)	(20.56)
Executive functions			3.04		2.95
			(3.63)		(3.67)
N	81	81	80	79	78
R-squared	0.04	0.12	0.15	0.13	0.16
Adjusted R-squared	0.03	0.09	0.11	0.10	0.11

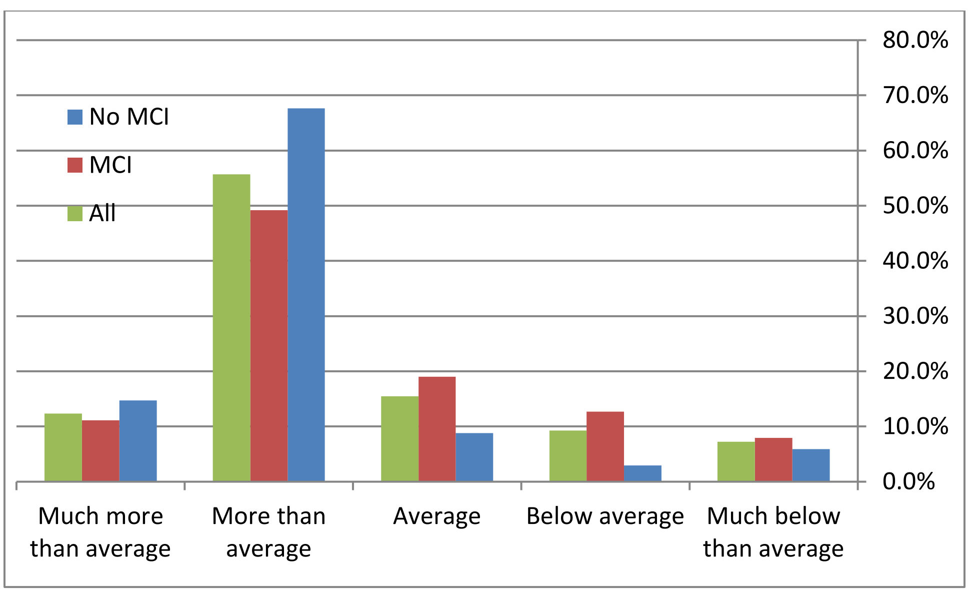
P<0.01 ***
P<0.05 **
P<0.1 *

Table 10: Hyperbolic Model

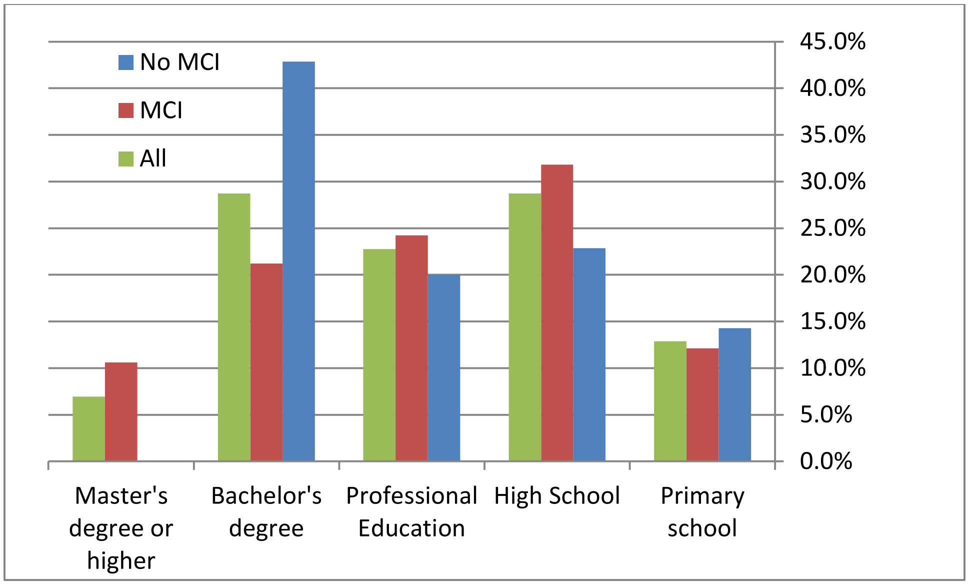
Hyperbolic					
	(1)	(2)	(3)	(4)	(5)
k	0.0103633*** (0.0018063)	0.0458813*** (0.0101166)	0.0473492*** (0.0100933)	0.0487674*** (0.0098005)	0.047375*** (0.0135927)
Executive functions		-0.0003618*** (0.0000882)	-0.0003611*** (0.0000833)	-0.0003872*** (0.0000832)	-0.0003399*** (0.0001204)
Amount (0=200, 1=2000)			-0.0015505* (0.0008856)	-0.002095*** (0.0007715)	-0.0024094*** (0.0007643)
Household income+					-0.0010088 (0.0013737)
MCI 0=No 1=Yes				0.002938** (0.0014346)	0.0037099** (0.0017676)
Gender 1=women					0.0003592 (0.0019993)
N R-squared adjusted R^2	1000 0.6472 0.6436	1000 0.69 0.6869	1000 0.69 0.6869	1000 0.6947 0.6916	960 0.6889 0.6857

P<0.01 ***
P<0.05 **
P<0.1 *

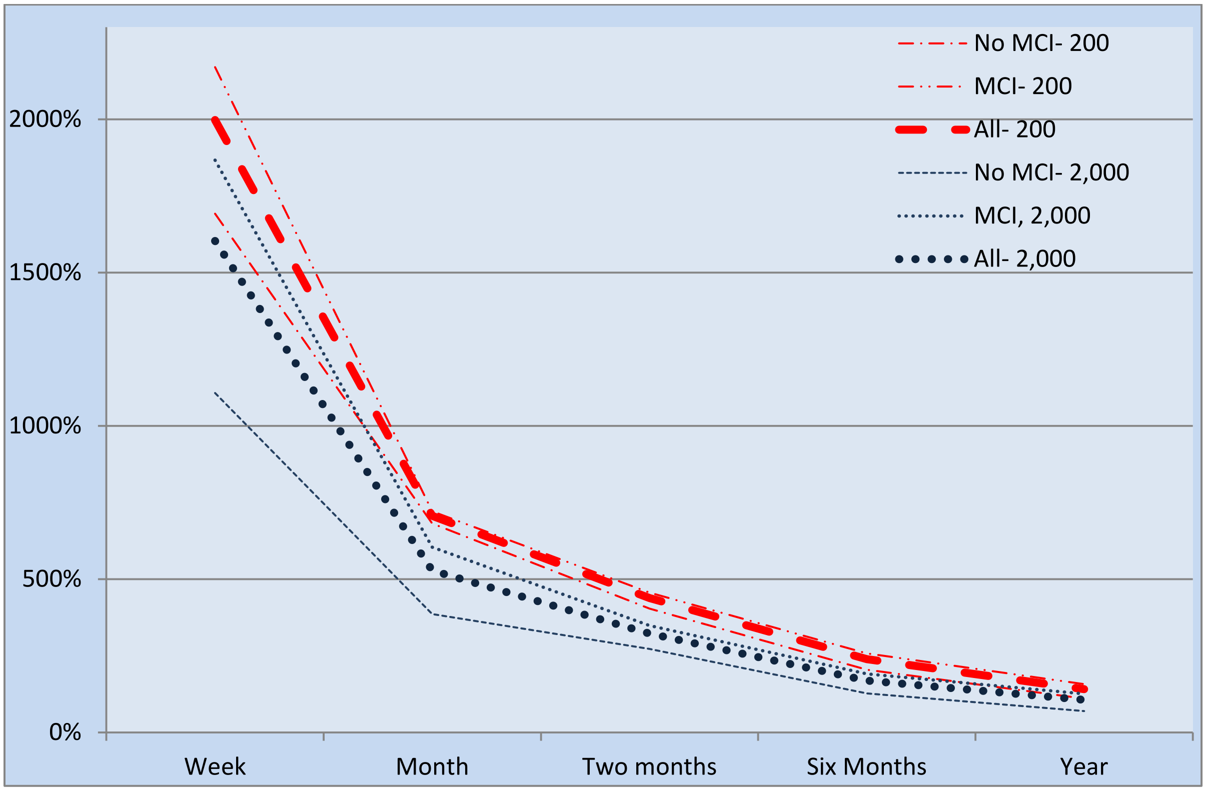
Graphs



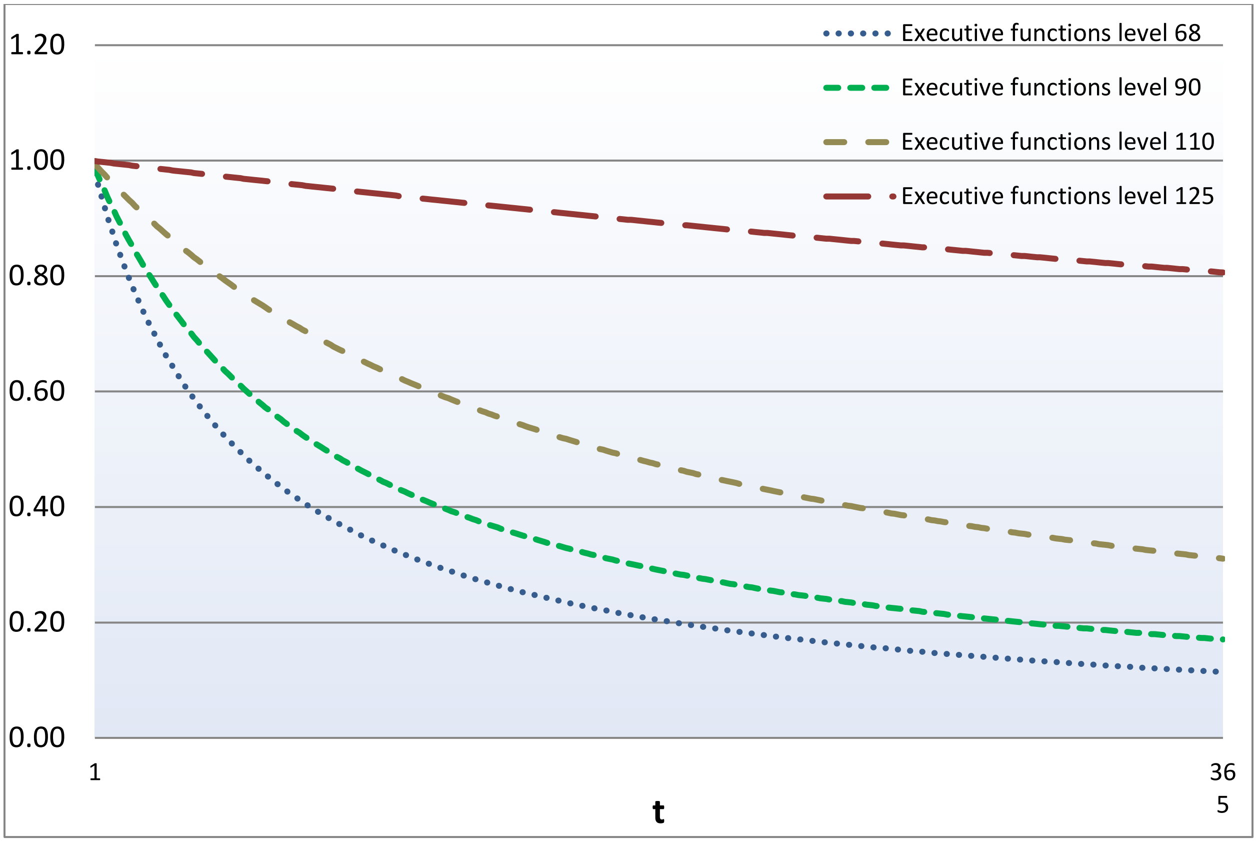
- Graph 1: Respondent income levels -



- Graph 2: Respondent education levels –



- Graph 3: SDR over time and by group –



Graph 4: hyperbolic model