Ratio Mathematica Volume 43, 2022

A multidisciplinary approach to decompose decision-making process in the context of intertemporal choices

Roberta Martino[1]
Viviana Ventre[2]

Abstract

This paper takes place in the context of intertemporal choices through a multidisciplinary approach involving behavioral finance, mathematical finance, temperament theory and multicriteria models of decision support techniques. The motivation at the basis of the present study is the need to investigate the discrepancy between the normative models assumed by classical finance and the actual actions of the investors. Therefore, a methodology that allows to understand the extent to which decision-making process depends on the cognitive and emotional characteristics of the individual is presented. To achieve the aim, preferences are discussed in terms of the decision-maker's limited rationality through the relationship between decision inconsistency, impatience, and subjective perception of time. The applicability of our methodology addresses the strategic personalization. In fact, the irrational attitudes associated with investors' seemingly superficial choices have led to the need for customer profiling operations in the European regulatory framework, introduced in 2014/65/EU Directive.

Keywords: anomalies; impatience; intertemporal choices; perception of time; strategic personalization.
2010 AMS subject classification: 91B08.*

[1] Dept. of Mathematics and Physics University of Campania "L. Vanvitelli" Viale A. Lincoln, 5 – 81100 Caserta, Italy; roberta.martino@unicampania.it). Corresponding author. 0000-0002-2195-8715
[2] Dept. of Mathematics and Physics University of Campania "L. Vanvitelli" Viale A. Lincoln, 5 – 81100 Caserta, Italy; viviana @unicampania.it. 0000-0001-5314-5770

* Received on October 19, 2022. Accepted on November 2, 2022. Published on December 30, 2022. doi: 10.23755/rm.v43i0.880.

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1 Introduction

Intertemporal choices are the type of decision in which consequences are distributed over time. Most daily decisions fall under this definition: buying a car, deciding on a university plan, and undertaking an investment (Lu and Yang, 2015). The uncertainty that characterizes the decision-making context of intertemporal choices makes evaluating and selecting the alternative extremely difficult, both because of the amount of information required to analyze the available prospects and because of the emotional intensity of the decision maker involved. The Discounted Utility Model defined by Samuelson (1952) is the essential mathematical reference for intertemporal preferences. However, when compared with empirical evidence, the preferences expected by the model do not correspond to the actual actions of the decision-maker. Hyperbolic formulations of the discount function are more in line with the description of the individual's behavior than the exponential formulation assumed by the Discounted Utility Model. The application of cognitive psychology to decision-making behavior has led to the realization that decision-making is subject to a condition of bounded rationality (Simon, 1957) and systematic distortions of the cognitive process (Kahnemnan, 2017). Furthermore, the countless behavioral differences clarify the impossibility of studying cognitive processes without considering a categorization of the client (Pompian, 2008, 2012).

To formalize a method able to quantify the mechanisms responsible for hyperbolic discounting and to project the analysis of the decision-making process into strategic personalization, a multidisciplinary approach is used. The disciplines used are: mathematical finance to mathematically describe the decision-maker's behavior, personality theory to identify behavioral classes, behavioral finance to justify the shift from choice to decision style, multicriteria models to get at a decomposition of the decision making process with respect to the factors considered in the other disciplines used.

To investigate the influence of the individual's cognitive and behavioral attitudes on the evaluation and selection of alternatives, factors affecting choice are quantified by the degree of impatience and subjective time bias. These values are then used to definethe weights of the Analytic Hierarchical Process (Saaty, 1980, 2008), allowing a decomposition of the decision-making process with respect to the classes of temperaments (Keirsey, 1998) and the anomalies of the Discounted Utility model (Loewenstein and Thaler, 1989, 1992).

The applicability of the present work refers to the Markets in Financial Instruments Directive, 2014/65/EU (MiFID 2), in which the importance of individual client characteristics is emphasized. It requires the analysis of risk appetite or risk aversion and the importance of communication, knowledge, and understanding relating to portfolio management.

The paper develops as follows: in the second section, decision inconsistency is discussed and contextualized with respect to behavioral theories; in the third section, the methodology is presented; discussion and conclusion follow.

2 Psychological mechanisms of hyperbolic discounting

The Discounted Utility Model assumes that the utility of an intertemporal prospectus $(x_1, t_1; \dots; x_n, t_n)$, is calculated as $\sum_{i=1}^{n} U(x_i) f(t_i)$, where $f(t_i)$ is the discount function and $U(x_i)$ is the cardinal utility of the outcome x_i. The performance of the discount function is crucial to the selection of alternatives and depends on how the individual perceives the indeterminacy of the future. Initially, the discount function was assumed to have an exponential trend. Empirical evidence (Green and Myerson, 1996; Dasgupta and Maskin, 2005; Lu and Yang, 2015) motivated the formulation of discount functions with a hyperbolic trend that better represents actual investor behavior (Green and Myerson, 1997). The fundamental elements of the Discounted Utility Model are discount rates and impatience. The first is defined as $\rho(t) = -\frac{f'(t)}{f(t)}$ and indicates the rate at which the discount function decreases over standard period (Read, 2004); the latter is impatience which indicates the amount of money one is willing to lose to receive a unit of money immediately (Cruz Rambaud and Muñoz Torrecillas, 2016). The exponential model assumes a constant value for the discount rate and impatience, while in hyperbolic models both quantities decrease over time (Prelec, 2004).

To clarify the consequences of exponential discounting, let be SS and LL two results, one smaller and sooner (SS) and the other larger and later (LL). A rational decision-maker can indifferently choose one of the two available options, the choice depends on how the uncertainty of the future is perceived. The choice is temporal consistent if the preference remains constant over time, as shown in Figure 1 for (a) and (b). Hyperbolic discounting means that preferences are not constant over time generating the mechanism of temporal inconsistency, as shown in Figure 1 for (c).

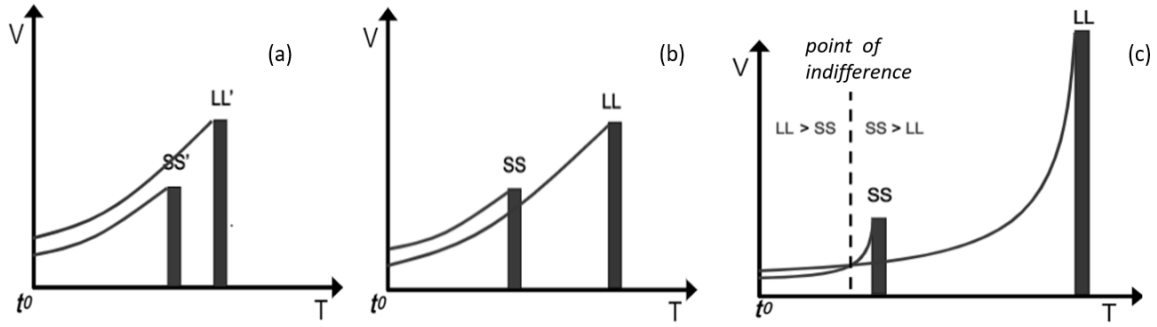

Figure 1: Images (a) and (b) describe temporally consistent preferences; image (c) shows temporally inconsistent choices.

Ventre et al. (2022 (a)) investigated the phenomenon of temporal inconsistency by describing the anomalies of the Discounted Utility Model (Loewenstein and Thaler, 1989) in terms of decreasing impatience. They made it possible to understand that the gap between empirical and normative preferences lies in the emotional drives that condition the decision-maker. Considering that the uncertainty of the future generates a haste

mechanism that makes individuals more impatient in the first period, inconsistency can be seen as incoherence in the decision-making process when assessing prospects that are close or not to the present (Ventre et al., 2022 (a)). Table 1 shows some results of Ventre et al. (2022, (a)).

The description in Table 1 of the bias-related anomalies defines a connection between the behavioral attitudes of individuals and their decision-making process. The direct extension of this result turns to personalized behavioral finance. Indeed, psychology has made it clear that individuals are prone to different biases to varying degrees according to their behavioral characteristics (Kahnemnan and Tversky, 1979; Pompian, 2008, 2012; Pompian and Longo, 2005). Over the years, various theories that have tried to classify individuals in behavioral groups (Keirsey and Bates, 1984; Myers, 1980; Jung, 1923). The consequence is that, since different behavior defines different decision-making styles, the way of dealing with inter-temporal choices is different. For this reason, Pompian (2012) defined classes of behavioral investors by cross-referencing behavioral finance studies and Keirsey (Keirsey and Bates, 1984) temperaments.

The relationship between temperaments and BIT is shown in Table 2. A further important result in this context is described by McKenna et al. (2003), who define different communication modes for each BIT.

In addition to a behavioral classification, the Temporal Approach Theory (Zimbardo and Boyd, 2008), shown in Table 3, suggests that how individuals relate to time also influences decision-making.

Although the objective nature of chronological time is obviously recognized, the term subjective time denotes everyone's perception of time passing. From a neurological point of view, it is still unclear how and where the subjective perception of time develops in mind.

With respect to decision-making, Wittman et. al (2010) proved that the perception of time can be deviated from the experimental context, as it depends on the characteristics of stimuli (Fraisse, 1984) and how these interact with the emotional sphere of the decision-maker (Noulhiane et al., 2007 ; Droit-Volet and Gil, 2009). Therefore, the evaluation of intertemporal prospects is strongly influenced by subjective time (Agostino et al., 2021; Zauberman et al., 2009) as it affects emotional factors and the perception of the uncertainty of the future. By exploiting the mathematical properties of the discount function, it is possible to observe that the gap between empirical evidence and the normative model is directly related to a different perception of the time instants considered in the schedules to be evaluated. Let's observe that a hyperbolic discount function is characterized by a greater speed in the initial period, related to the property of decreasing in impatience (Cruz Rambaud and Muñoz Torrecillas, 2016; Prelec, 2004).

Anomaly	Description	Results by Ventre et al. (2022, (a))
Delay effect (Loewenstein and Thaler, 1989)	$(x,s) \sim (y,t) \Rightarrow$ $(x,s+h) \prec (y,t+h)$ $s < t, 0 < x < y$	The rate of variation of the discount function $f(t)$ is decreasing
Magnitude effect (Benzion et al., 1989, Noor, 2011)	$(x,s) \sim (y,t) \Rightarrow$ $(X,s) \prec (Y,t)$ $s < t, x < y, x < X < Y:$ $\frac{U(y)}{U(x)} = \frac{U(Y)}{U(X)}$	$(x,s) \sim (y,t) \Rightarrow (X,s) \prec (Y,t)$ $\leftrightarrow U(y) - U(x) < U(Y) - U(X)$
Sign Effect (Loewenstein and Thaler, 1989; Cruz Rambaud and Sánchez Pérez, 2018)	$(x,s) \sim (y,t) \Rightarrow$ $(-x,s) \succ (-y,t)$ $s < t, 0 < x < y$	If the utility of a result is calculated as $V(x)$, where $\varepsilon > 1$ (according to the Prospect Theory (Kahneman and Tversky, 1979)) and U is concave ($U'' < 0$), then $(x,s) \sim (y,t) \Rightarrow (-x,s) \succ (-y,t)$

Table 1: Some results by Ventre et al. (2022, (a)).

Keirsey's Temperament	BIT
Artisan. It is the temperament which acts. Spontaneous and lovers of freedom	*Accumulator.* Interested in accumulating wealth
Guardian. Cautious, reliable, and disciplined, concrete and organized with a strong sense of responsibility and duty	*Conservative.* Protector of their heritage
Idealist. Interested in personal growth and development, skilled to inspire and clarify	*Follower*. Not interested in financial matters
Rational. The most theoretical temperament and attracted by problem solving.	*Independent.* The investment is procedure to be understood and controlled

Table 2: Keirsey's Temperament and BIT.

Temporal approach	**Meaning**
Positive past	Individuals oriented towards good memories of the past
Negative past	Individuals addressing the past with a negative attitude
Hedonistic present	Individuals living in the present and enjoying the moment
Fatalistic present	Individuals who live life as if everything were already written
Future	Individuals aiming at their own projects and actions
Transcendent future	Individuals more focused on what comes after life

Table 3: Psychological theory of the Temporal Approach.

Figure 2 shows in which relation $f(t)$ and $\tilde{f}(t)$ are, where $f(t)$ is an exponential discount function and $\tilde{f}(t)$ is an hyperbolic discount function.

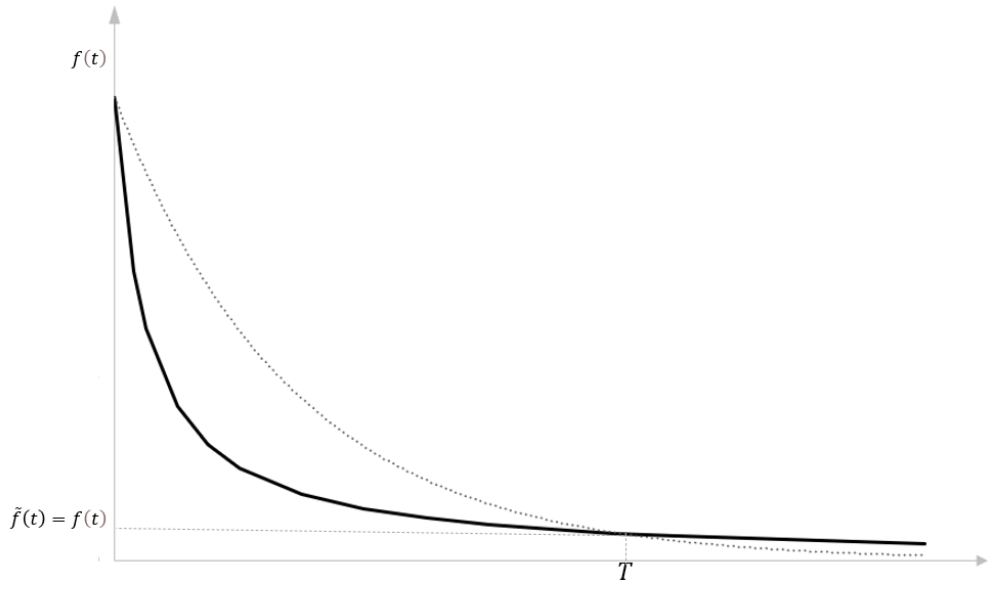

Figure 2: Relationship between a hyperbolic discount function (in black) and an exponential discount function (in grey).

So $\forall t \in [0, T]$, $\tilde{f}(t) < f(t)$ and from the decreasing monotony property of the discount function, there exists $\tilde{t} < t$ such that $f(t) = \tilde{f}(\tilde{t})$. Similarly, $\forall t \in [T, +\infty]$ $\tilde{f}(t) > f(t)$, i.e., exists a point $\tilde{t} > t$ such that $f(t) = \tilde{f}(\tilde{t})$. What has been observed is equivalent to stating that the subjective perception of time is decisive for hyperbolic discounting as it reduces the perceived intervals up to the T point and dilates them after the T point. From this perspective, it is possible to define a measure of subjective time-related inconsistency. If $y(t)$ is the best exponential function that approximates $\tilde{f}(t)$ a measure for inconsistency based on time perception bias is $d = \max_{t \in [0,T]} \{\tilde{f}(t) - y(t)\}$. A study investigating the relationship linking decreased impatience, discount rate

and subjective perception of time was conducted by Ventre et al. (2022, (b)) and Ventre and Martino (2022). Specifically, through a direct comparison of consistent and inconsistent preferences, the influence of time perception in intertemporal choices is formalized and empirically proven.

3 Decomposition of the decision-making process using AHP

The Analytical Hierarchical Process (Saaty,1980, 2008) is a multi-criteria method to support the decisional process. The structure is based on directed graphs (Knuth, 1973) and its implementation allows the decomposition of a problem into its most basic components. Its characteristics are encapsulated in its name: the technique is analytical because it decomposes the main problem; it is a process because it develops with precise actions; it is hierarchical because the structure consists of several levels.

The first level represents the general objective, which in our case, is to understand how much the combination of temperament and inconsistency weighs on the evaluation of the available intertemporal perspectives. The structure is constituted as shown in Figure 3 and it represents an extension of the structure presented by Ventre et. al (2022, (c)).

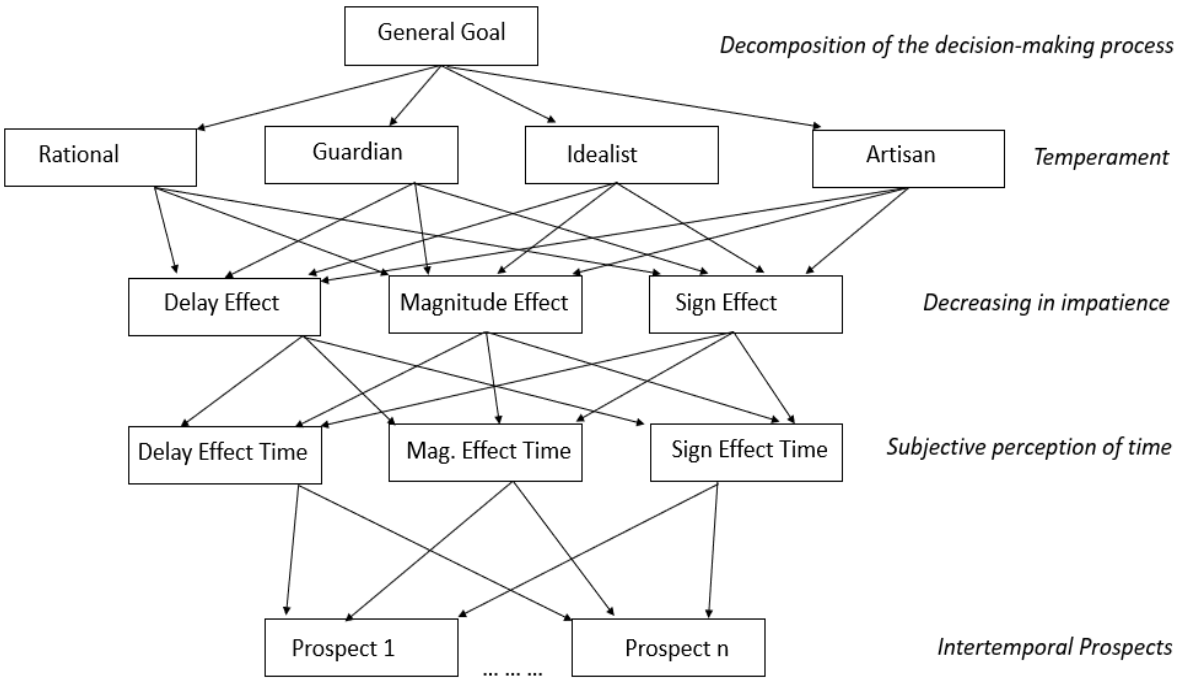

Figure 3: AHP structure.

To construct the pairwise comparisons matrix to obtain the local weights, and thus the global weights, we can exploit the information obtained in Section 2.

The matrix of the first level can be constructed by considering the "The Keirsey Temperament Sorter II" (Keirsey, 1988). The questionnaire determines a vector

indicating for each score how much temperament is represented for the individual. The pairwise comparison matrix is defined in Table 4.

General Goal	Rational	Guardian	Idealist	Artisan
Rational	1	$\frac{score\ of\ G}{score\ of\ R}$	$\frac{score\ of\ I}{score\ of\ R}$	$\frac{score\ of\ A}{score\ of\ R}$
Guardian	$\frac{score\ of\ R}{score\ of\ G}$	1	$\frac{score\ of\ I}{score\ of\ G}$	$\frac{score\ of\ A}{score\ of\ G}$
Idealist	$\frac{score\ of\ R}{score\ of\ I}$	$\frac{score\ of\ G}{score\ of\ I}$	1	$\frac{score\ of\ A}{score\ of\ I}$
Artisan	$\frac{score\ of\ R}{score\ of\ A}$	$\frac{score\ of\ G}{score\ of\ A}$	$\frac{score\ of\ I}{score\ of\ A}$	1

Table 4: Pairwise comparison matrix between Temperament and General Objective.

For the level of impatience decrease, it is possible to calculate the hyperbolic factor for each anomaly with respect to each temperament. The hyperbolic factor, for the indifference pairs $(x,s)\sim(y,t)$ $(x,s+\sigma)\sim(y,t+\tau)$ $s<t, x<y, \tau>0$ is defined as (Rohde, 2010):

$$H(s,t,\ y,\tau)=\frac{\tau-\sigma}{t\sigma-s\tau}$$

The questionnaire for constructing the hyperbolic factor and the relative pairwise comparison matrix are in Table 5 and Table 6, respectively.

As discussed in Section 2, the hyperbolic trend defined by the decrease in impatience is related to the subjective perception of time. By constructing a discount function using the interpolation technique for each anomaly, it is possible to obtain the degree of inconsistency as the maximum distance between the hyperbolic discount function and its best exponential approximation. The questionnaire for constructing the hyperbolic function and the relative pairwise comparison matrix are given in Table 7 and Table 8 respectively. The questionnaire proposed in Table 7 is based on the application conducted by Ventre et al. (2022, (b)) and Ventre and Martino (2022).

Instead, the last pairwise comparison matrix is defined by a panel of experts who determine how much the prospectus could contribute to that type of anomaly. In fact, since the decision-making context of intertemporal choices is so complex that the selection of an alternative can be modelled as a multi-criteria group decision problem (Wu et al., 2022).

Anomaly	Variable	Question
Delay Effect t fixed, s fixed, τ fixed	x	You must receive a sum of y_{DELAY} in t months, not before the set date but, alternatively, there is the possibility to immediately collect a certain result by reducing the total to be collected. To accept the offer, how much at least do you want to receive today?
y_{DELAY} fixed	σ	You must receive a sum of y_{DELAY} in t+ τ months, not before the set date but you are given the opportunity to anticipate the application and collect a result of x instead of $y_{DELAY.}$. To accept the offer, how long do you want to receive the x-digit?
Magnitude Effect t fixed, s fixed, τ fixed	x	You must receive a sum of $y_{MAG.}$ in t months, not before the set date but, alternatively, there is the possibility to immediately collect a certain result by reducing the total to be collected. To accept the offer, how much at least do you want to receive today?
$y_{MAG.}$ fixed $y_{DELAY} > y_{MAG.}$	σ	You must receive a sum of $y_{MAG.}$ in t+ τ months, not before the set date but you are given the opportunity to anticipate the application and collect a result of x instead of $y_{MAG.}$ To accept the offer, how long do you want to receive the x-digit?
Sign Effect t fixed, s fixed, τ fixed	x	You must pay a sum of y_{SIGN} in t months, not before the set date but you are given the option to pay a lower result as long as the payment is paid on the same day. What is a figure that you think you could offer to accept your offer?
y_{SIGN} fixed $y_{SIGN} = -y_{DELAY}$	σ	You must pay a sum of y_{SIGN} in t+ τ months, not before the set date but you are given the opportunity to pay x instead of $y_{SIGN.}$. To accept the offer, how soon would you commit to making payment?

Table 5: Questions to obtain the pairwise comparison matrices between temperaments and anomalies.

Temperament $\boldsymbol{i}$	Delay Effect	Magnitude Effect	Sign Effect
Delay Effect	1	H_{DELAY}/H_{MAG}	H_{DELAY}/H_{SIGN}
Magnitude Effect	H_{MAG}/H_{DELAY}	1	H_{MAG}/H_{SIGN}
Sign Effect	H_{SIGN}/H_{DELAY}	H_{SIGN}/H_{MAG}	1

Table 6: Pairwise comparison matrices between temperaments i and anomalies.

Anomaly	**Question**	**Function**
Delay Effect $U_D(x(0))$ *fixed* $t_0 = 0$	*You have to receive* $U(x(t_i))$ *euros today, how much do you want to receive in* t_{i+1} *days to consider the offer equivalent?*	$f(t) = \begin{cases} f(0) = 1 \\ f(t_{i+1}) = \dfrac{f(t_i) * U(x(t_i))}{U(x(t_{i+1}))} \end{cases}$
Magnitude Effect $U_M(x(0))$ *fixed* $U_M(x(0)) < U_D(x(0))$ $t_0 = 0$	*You have to receive* $U(x(t_i))$ *euros today, how much do you want to receive in* t_{i+1} *days to consider the offer equivalent?*	
Sign Effect $U_S(x(0))$ *fixed* $U_S(x(0)) = -U_D(x(0))$ $t_0 = 0$	*You must pay* $U(x(t_i))$ *euros today but you don't have the affordability. As far as, how much are you willing to pay in* t_{i+1} *days to consider the offer equivalent?*	

Table 7: Questions to obtain the discount function for each anomaly.

Anomaly *i*	Delay Effect	Magnitude Effect	Sign Effect
Delay Effect	1	d_{DELAY}/d_{MAG}	d_{DELAY}/d_{SIGN}
Magnitude Effect	d_{MAG}/d_{DELAY}	1	d_{MAG}/d_{SIGN}
Sign Effect	d_{SIGN}/d_{DELAY}	d_{SIGN}/d_{MAG}	1

Table 8: Pairwise comparison matrices between temperaments i and subjective perception of time.

4 Discussion

The present work has discussed a multidisciplinary approach to decompose the decisional process in the context of intertemporal choices. The purpose of the paper is to present a method for investigating the behavior of individuals in a decision-making context of uncertainty. The applicability refers to the definition of classes of decision-makers based on decision-making style and behavioral characteristics. The creation of investor profiles were introduced following the major crises of the past decade to protect individuals. Uncertainty analysis is fundamental to the study of asset pricing and entrepreneurship (Giffrod, 2003). Therefore, the present work turned to a classification based on the dynamics responsible for the anomalies in the Discounted Utility Model.

The quantification of cognitive factors has been obtained through the concept of decreasing impatience and subjective perception of time. The proposed method has been justified in Section 2 showing that the behavior between the discount and hyperbolic function differs due to the lack of elements in the normative model that do not consider the emotionality and cognitive limitations of the decision maker. In fact, the decrease in impatience can be interpreted as the inconsistency in the decision-making process between the short and the long run, the time perception bias can be associated with the projection mechanism that individuals implement to evaluate an event that has not yet happened (Loewenstein, 1996; Loewenstein et al., 2003; Loewenstein et al., 1998; Wheeler et al., 1997). Developments in cognitive psychology presented in Section 2 motivated the projection of the results discussed within personality theory.

This made it possible to construct the AHP structure to decompose the decision-makingprocess into its main components and weigh the influence of behavioral attitudes and cognitive abilities on the evaluation of alternatives.

The originality of our approach lies in incorporating the following motivations into a single methodology: temporal inconsistency is related to the emotional drives of the decision-making context; behavioral differences among Keirsey temperaments indicate the impossibility of determining strategies that give the same degree of satisfaction to

all individuals; psychological mechanisms and propensities for cognitive biases for each individual must be taken into account to investigate decision making; the lack of emotional factors in the normative model results in a different perception of time and a decreasing degree of impatience; to improve the choices of individuals, it is necessary toproject considerations in the context of personalized behavioral finance in which strategic diversification must propose different strategies, different ways of representing and communicating intertemporal prospects.

5 Conclusions

The applicability of the present model is related to the investor profile creation operations required by the European Directive MiFID 2 (Markets in Financial Instruments Directive, 2014/65/UE). Since the decision maker suffers from systematic cognitive distortions, limited rationality, and emotional impulses that distort decision-making, financial advisors must assess the suitability of the client and the appropriateness of proposed alternatives.

The broad definition of intertemporal choices and the multidisciplinary approach used allow for numerous lines of future research. In the field of behavioral finance, understanding how subjective perception of time affects decision-making can contribute to understanding how individuals interface with investment and debt dynamics (Hoang and Hoxha, 2016). Because the perception of time is linked to the emotional sphere (McLoughlin, 2019; Droit-Volet and Meck, 2007), the relationship between investor emotions and financial assets can be further explored (Schmeling, 2009). Finally, the description of risk as a feeling (Loewenstein et al., 2001) determinesa connection between time and prospect theory by improving the description of risk propensity or aversion (Wang et al., 2011; Broihanne et al., 2014; Sun and Li, 2010).

Regarding neuroscience, because time has neurological origins, our multidisciplinary approach can help clarify the difference between impulsivity and impatience, which are instead confused in the context of intertemporal choices (Berlinet al., 2004; McLeish, 2007). However, because impulsivity is described as a lack of self-control (Monterosso and Ainslie, 1999), it can be seen as a behavioral attitude. Instead, impatience is a feeling versus expectation.

In conclusion, the present paper has proposed a multidisciplinary method to calibrate strategies according to behavioral profile and quantification of inconsistency. In the perspective of strategic personalization, the applicability also extends into the social sphere considering that hyperbolic preferences are associated with procrastination mechanisms, depressive attitudes (Petry, 2001; Prelec, 2004), and gambling addiction (Calluso et al., 2020). Indeed, as argued by Thaler and Sunstein (2019) it is possible to guide individuals toward better alternatives by making use of the same cognitive biases.

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