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Self-Control against Half-Intuitive Reactions

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Abstract

People like to enjoy immediate impulsive rewards and delay costs. The sophisticated ones are aware of this and try to control themselves. However, in certain situations when impulses seem irrelevant and insignificant, people react following their intuitive desires and usually end up with suboptimal results. This paper bridges the literature on Self-Control and Bounded Rationality and offers a model which explains intuitive reaction processes. It proposes an optimal mental state and reaction strategies to tackle the impulsive reactions which lead to negative results.

Keywords: Self-control, Bounded Rationality

A student would like to pass an exam. He decides to study. Walking to a library, he meets a friend who invites him to a party. The student turns down the party proposal. In the library, while he tries to understand an important part in a book, a person walks past by his reading table and hums a melody from a song. The student acknowledges the presence of the passerby, recognizes the melody, recalls some memories, and loses his concentration on the book. Physically, he is still sitting; his eyes are looking at the book. Mentally, he is half-seeing the book and half-wondering about something else. He fails the exam.

The situation that we would like to study involves an individual who tries to do certain activities according to his plan. Let us look at it in three stages: a long-term or planning stage, a short-term or self-control stage, and an extremely impulsive or half-intuitive stage.

The student plans to study in the *planning stage*. Then, he follows the plan and manages to go to the library instead of the party. This is the *short-term* stage which involves *self-control* actions to turn down tempting choices. He might imagine what would happen if he fails and uses that fear as an *internal commitment* mechanism to suppress the *desire* to party. The short-term stage entails one important character of human nature known as *time inconsistency* which involves hesitations to follow the predefined plan due to short-term *impulses*. In these first two stages, the student has full conscience of the relevant costs, benefits, and choices when he makes decisions. We may say that he is *rational*.

The third stage starts when he hears the melody, recalls certain memories, and loses the concentration on the book. Here, impulses take the form of minor distractions and the student reacts partly following his *perception* and *intuition*. We generally say that his *mental state* is not fully rational or that it is *bounded rational*. Besides, he also does not take these impulses as seriously as he does with the party invitation. Thus, self-control is not in sight. We call this the *extremely impulsive or half-intuitive stage* and label the situations which are characterized by the elements of this stage as being in the *extremely impulsive setting*. They are the situations of our focus.

The aim is to identify ways to respond better in the extremely impulsive settings. The pioneering attempt to find *the optimal behavioral rules* or *reaction strategies* comes from a study by Bénabou and Tirole (2004). According to them, individuals control short-term impulses to respect their self-reputation. They are strict in controlling their behavior when they remember past lapses and wish to avoid damaging their reputation. Different levels of self-reputation and the ability to recall lapses strengthen their willingness to resist impulses. Bénabou and Tirole broadly classify individuals into two groups according to their strength of will: the strong-willed who generally tries to persevere and the weak-willed who gives up more easily. To study different behavioral responses of each group, they subsequently define four behavioral rules. Impulsive behavior applies when each group acts following his/her impulses. Flexible rule believer gives up only when the cost is too high. With bright-line behavior, both groups always persevere. And with compulsive behavior, the strong-willed

always perseveres and the weak-willed always gives up. In some cases, individuals decide to act myopically and adopt impulsive behaviors; while in other cases, individuals adopt excessively rigid rules which in turn lower their welfare. In fact, different situations call for different behavioral rules. One should not be too harsh to oneself when the cost of self-control is far too high. Neither should one be over impulsive to the level that damages self-reputation. Hence, Bénabou and Tirole conclude by suggesting optimal behavioral rules in each situation.

This study follows the similar research path with the objective to find optimal behavioral rules allowing individuals to control their own undesirable impulses. While Bénabou and Tirole focus the short-term stage, here we investigate the issue in the extremely impulsive stage which perception and intuition strongly influencing individuals' reactions. This places us one step away from fully rational self-control models and one step closer to the bounded rationality literature.

Let us see from our continuing example to define the issue at stake. When the student loses his concentration, what is the problem? If we slowly reconsider the situation: he would like to pass the exam so he plans to study, comes to the library, *loses his concentration*, and finally fails the exam. This series of actions leads to the eventual result. To come to the library and study certainly do not guarantee that he will learn necessary materials for the exam. It is the effective learning by means of mental concentration and thinking processes that counts. If we ask him whether he knows this fact, we surely get a positive reply. No one expecting to pass the exam plans to lose his concentration to study. So, the problem comes from distractions which seem unimportant at that time, in the extremely impulsive setting. The distractions match well with his intuitive reactions, so his mind accommodates them naturally and shifts away from concentrating on the book. We suggest that the key determinants are the student's mental state and its response speed. If he is very determined and his mind concentrates on studying, it would be more difficult for him to be distracted. So, we have to identify a set of behavior or mind-set he should adopt so that he can reinforce his mind to concentrate and suppress distractions.

The impulsive reactions to these distractions usually lead to suboptimal results. In fact, these reaction patterns may breed bad habits and act as endogenous constraints to one's making an optimal choice. They can eventually cause major undesirable consequences. Because of this, handling these reactions properly removes constraints to the objective function and enhances utility.

One possible application is on education and labor supply efficiency. From a micro view, this knowledge can help students or workers manage their concentration and suppress distractions. From a macro view, this may lead to some changes in the ways to organize the class or working conditions. Perhaps before each class, a teacher should present objectives and important points of the session. We may allocate time for students to meditate to prepare their minds. After each session, the teacher calls for full attention, concludes and reviews important points to help relate important concepts with those from previous sessions. Concentration of students should also

be considered to determine various aspects of the learning session to make sure that it comes in an absorbable manner. Similarly, workers work more efficiently when they concentrate. The working conditions should be arranged to accommodate that. Positive changes will increase the overall labor supply efficiency, competitiveness and happiness.

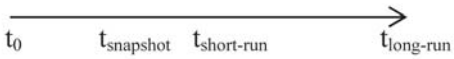
Before turning to the model, we introduce few concepts:

Definition 1 ***(Activities)*****:** Let a mental-supply bundle H consists of a sequence of activity inputs $h^+_1, h^+_2, \ldots, h^+_n$ which are necessary and efficient to produce a mental output H'. A bundle I is defined similarly. Hence, $H = \{\boldsymbol{h}^+\}$ and $I = \{\boldsymbol{i}^+\}$. $\boldsymbol{h}^-$ and $\boldsymbol{i}^-$ consist of activities which are not the members of $\boldsymbol{h}^+$ and $\boldsymbol{i}^+$ respectively. Loosely, we use the terms activity, sub-activity, and event to mean the same thing, the mental-supply container.

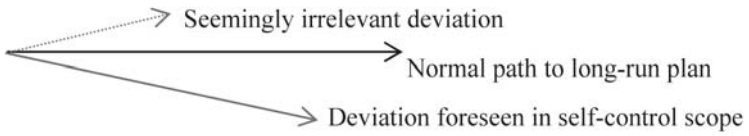
From the example: *H´ = {studied materials for the exam}*, *H = {turn to the related chapters, look at the text, read the first sentence, understand the first sentence,…}*, *I´ = {daydreaming}*, and *I = {recognize the melodies, recall some memories, create a story,…}*.

Definition 2 ***(Extremely Impulsive Setting)*****:** An individual encounters an event i. The event is considered to be in the *extremely impulsive setting* if it meets the following three conditions at the time the event occurs.

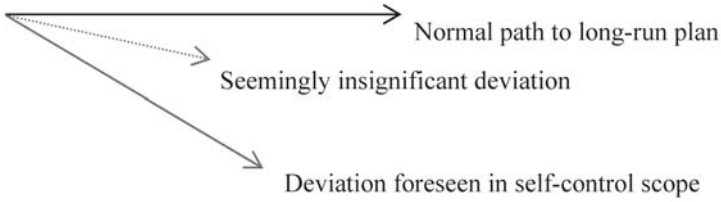
Condition EIS1 ***(Snapshot)*****:** The relevant time is very short, almost instantaneous. The individual defines this subjectively.



Condition EIS2 ***(Seemingly Irrelevant)*****:** While the event deviates ones from the long-run plan, the individual feels that the event i is irrelevant to his self-control scope.



Condition EIS3 ***(Seemingly Insignificant)*****:** While the event deviates ones from the long-run plan, the individual feels that the event *i* is insignificant to his self-control scope.



To clarify the above conditions: At the time the student briefly loses concentration, everything seems automatic and he is not even aware of it. He might have a slight flash of reflection but then his half-conscience considers that the distraction is insignificant and irrelevant. In this situation, the student encounters the event in the extremely impulsive setting as the three conditions are satisfied.

Definition 3 ***(Pareto-Superior Behavioral Rules*** or ***Optimal Reaction Strategy)*****:** A reaction R is (ex post) Pareto-superior to a reaction R´ if, when confronted with a series of events in the extremely impulsive settings, the individual is better off if the reaction R is played rather than the reaction R´. We will use this criterion to find the optimal reaction strategy.

The Model

Organization of the model:

I. Introduction
II. Mental State Formation: related components and their logical sequences
III. Reaction Determination: matching of mental state supply and demand
IV. The Optimal Reaction Strategy

I. Introduction

First, to locate the position and limit the scope of our model, we suggest that there are three decision systems: Long-term system (rational) in the outermost ring e.g. Becker's and Heckman's human capital formation models; Short-term system (rational but time-inconsistent) in the middle ring e.g. self-control models with the competition between willpower and desire, according to Hoch and Loewenstein (1991); and the EIS system (bounded rational or half-intuitive) in the innermost ring. We position our model in the EIS system, at the frontline where the individual reacts to the situation.

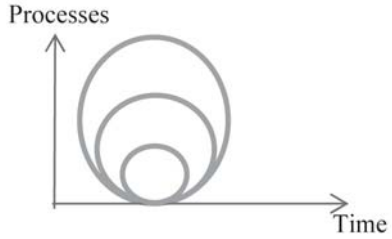


Illustration 1

To study self-control in the Extremely Impulsive Setting, we examine the issue in three steps: mental state formation, reaction determination, and the optimal reaction strategy.

II. Mental State Formation

The process starts from an individual who reacts to the activity *h* and suddenly faces with the event *i*. The event *i* is subsequently followed by an event *j* which is defined similarly. The event *i* is in the EIS as defined in Definition 2.

The mental state is endogenously determined by:

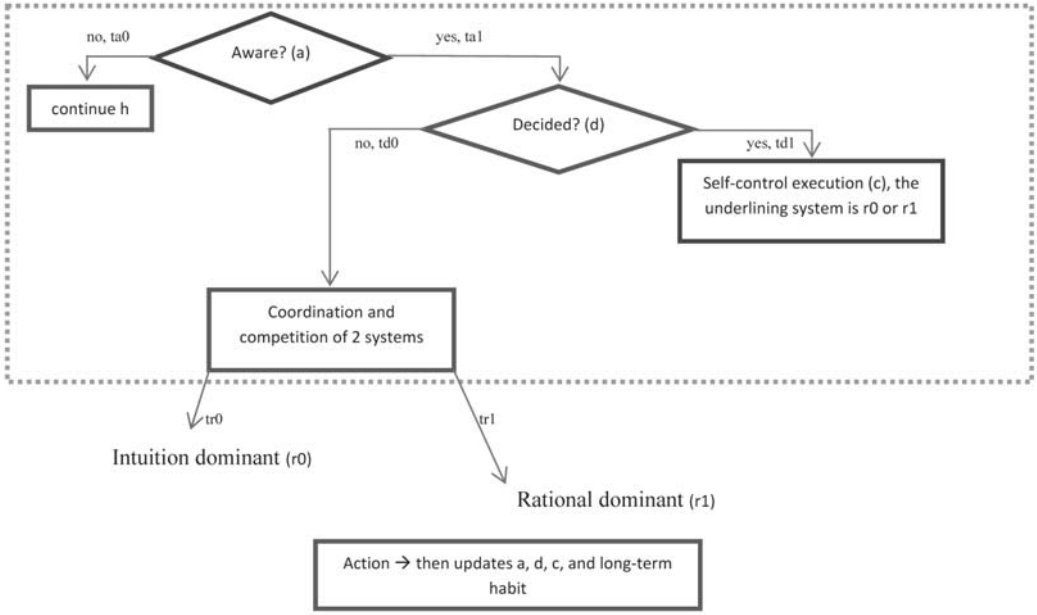


Illustration 2

Here are the related components and their sequence:

a) There are four processes, *a-process*, *d-process*, *c-process*, and *r-process*. Each process takes the event *i* as its input. The event *i* then passes through some checks. The outputs from the four processes form four elements representing a specific mental state.

Assumption 1 ***(Supply Formation Threshold)*:** There exists an information set $\ddot{I} = \{i_a, i_d, i_c, i_r\}$ representing the minimum threshold of each element for process a, d, c and r. This set is subjectively predetermined in the self-control stage. The member of the set $\ddot{I}$ is empty when that process is not predetermined. We define each element in the following part.

Definition 4 ***(Supply Formation Process)*:** The process takes the event *i* as its input and yields element p_i as its output. The *p-process*, *p(.)*, generates two possible outputs: *p0* or *p1*.

$p_i = p0$ if $i_p \notin \ddot{I}$, and
$p_i = p1$ if $i_p \in \ddot{I}$.

We will apply this definition to generate the following processes and their outputs.

b) The first process is *a-process* or *awareness*. The individual senses via his self-monitoring and becomes aware of the event *i* when the awareness of such activity is sufficiently clear to his conscience.

We represent this by:

$i_a \notin \ddot{I}$ *or* $i_a = \{\} \rightarrow a_i = a0$ *or i is not aware*
$i_a \in \ddot{I} \rightarrow a_i = a1$ *or i is aware*

With the element *a0*, the event *i* is not aware, so the individual continues with the activity *h*.

With the element *a1*, the next processes continue. (see the right-arm of the first node of Illustration 2)

c) *D-process* or *decided* represents a rapid check whether the reaction for the event *i* is predetermined. An element *d0* means there is no predetermined/predecided reaction so the reaction will have to be determined by the *r-process*, while an element *d1* means the individual has a predetermined reaction which might come from his habit, behavior, or preplanned self-control. In this process, the event *i* will also be judged whether it is a key event. That is $\{i\} \in \{\dot{i}^{+}\}$ *or* $\{i\} \in \{\dot{i}\dot{r}\}$. So the *d-process* assigns the experience value and the importance value.

In the same way, we write:

$i_d \notin \ddot{I}$ *or* $i_d = \{\} \rightarrow d_i = d0$
$i_d \in \ddot{I} \rightarrow d_i = d1$

d) *C-process* or *self-control execution* represents a self-control execution reaction for the event *i*. An element *c0* means the self-control execution is not successful while an element *c1* means it is successful.

We write:

$$i_c \notin \ddot{I} \text{ or } i_c = \{\ \} \rightarrow c_i = c0$$
$$i_c \in \ddot{I} \rightarrow c_i = c1$$

e) *R-process* or *rationale* represents the underlining decision system. An element *r0* means the reaction comes from the intuition system according to Kahneman (2003). An element *r1* represents the one from the rational system. Hence:

$$i_r \notin \ddot{I} \text{ or } i_r = \{\ \} \rightarrow r_i = r0$$
$$i_r \in \ddot{I} \rightarrow r_i = r1$$

f) To represent the four elements characterizing the mental state of the individual in the extremely impulsive setting, we use the four binary variables *a*, *d*, *c*, *r* written together as *{a,d,c,r}*. In general, we write the four elements *{a,d,c,r}* together. However, in the situations where the value of certain member is irrelevant, we mention only the relevant element(s). For example, the state *{a0}* refers to the first situation in the above table, the state *{a1}* refers to the other six situations, the state *{a1,d0}* refers to the states *{a1,d0,r0}* and *{a1,d0,r1}*.

g) The possible mental states include:

a	*d*	*c*	*r*	*definition*
0	0 or 1	0 or 1	0 or 1	With the state *{a0}*, either the activity *h* is uninterrupted or the total processing time is too long. Thus, the value of the remaining variables is not relevant. This represents the *unaware* reaction.
1	0	0 or 1	0	The event *i* is aware but there is no predetermined reaction. So, the value of *c-process* is not relevant. With this state *{a1,d0,r0}*, the individual reacts following his intuition. It is a *first-time intuition* reaction to the event *i*.
1	0	0 or 1	1	The event *i* is aware but there is no predetermined reaction. So, the value of *c-process* is not relevant. With this state *{a1,d0,r1}*, the individual reacts following his rationale. It is a *first-time rational* reaction.

a	*d*	*c*	*r*	*definition*
1	1	0	0	The event *i* is aware and there is a predetermined reaction but it is not successfully controlled. As a result, the reaction is not delivered as intended. The state *{d1,c0,r0}* implies that the reaction is influenced by habit, behavior and intuition. Hence, it is called a *habit-intuition* reaction.
1	1	0	1	The event *i* is aware and there is a predetermined reaction but it is not successfully controlled. As a result, the reaction is not delivered as intended. The state *{d1,c0,r1}* implies that the reaction is influenced by habit, behavior and rationale. Hence, it is called a *habit-rational* reaction.
1	1	1	0	The event *i* is aware and there is a predetermined reaction which is successfully controlled. This intuitive reaction is also delivered as intended. It is a *planned-intuition* reaction.
1	1	1	1	The event *i* is aware and there is a predetermined reaction and it is successfully controlled. This rational reaction is also delivered as intended. It is a *planned-rational* reaction.

Illustration 3

h) While the state *{a0}* and the four states *{a1,d1}* represent the reactions to the event, the two states *{a1,d0}* either lead to the unaware reaction *{a0}* or respond directly as the states *{a1,d0,r0}* or *{a1,d0,r1}* depending on the processing time. This is remarked in the dotted frame of Illustration 2. If the time for *r-process* takes too long, the state *{a0}* will be the reaction. If the element *{r}* is rapidly determined, one of the two states *{a1,d0}* will represent the reaction.

i) The link between self-control models and this model can be found in the four states *{d1}*. In the short-term stage, the individual decides on the optimal level of self-control; however, in the extremely impulsive setting, he does not have full control over the execution of such decision. The states *{d1,c1}* represent the cases where the self-control decision successfully influences impulsive reactions. The states *{d1,c0}* represent the cases where habit and behavior are more powerful than self-control decision.

j) Time is another key determinant in the mental formation phase. The total time to react includes the time to determine each element of the mental state. The reaction is not in time if it is slower than the speed of change of the event *i* to the event *j*. On the contrary, the reaction is in time when it is reacted before the event *i* changes to the event *j*.
This is represented by:

$T \equiv t_a+t_d+t_c+t_r$ for all elements of mental state for the event *i*.
$T > s_{ij} \rightarrow$ reaction is not in time, the state *{a0}* represents the reaction.
$T \leq s_{ij} \rightarrow$ reaction is in time. The reaction is $\{a,d,c,r\}_i$.

The result of the formation step is the mental state supply to the event *i* or $S_i = \{a,d,c,r\}_i$. Together with the required mental state demand for the event *i*, D_i, they determine the eventual reaction.

III. Reaction Determination

The required mental state for the event *i*, D_i, is exogenous to the model. The usual rules apply, so:

$S_i = D_i \rightarrow$ mental state supplied matches with the one demanded
$S_i > D_i \rightarrow$ mental state is over-supplied by S_i-D_i
$S_i < D_i \rightarrow$ mental state is under-supplied by D_i-S_i

In the first two cases, as highlighted in the forthcoming Illustration 4, the intended reaction is carried out. In the last case, it is not.

Different types of mental state may be supplied and demanded in order to produce different outputs. The model can be extended by including the production function which turns different mental state inputs to different outputs. As the focus here is on the optimal reaction strategy, we directly present the matching results:

Definition 5 (Mental Supply Effects):

Variable *A* is defined to capture the effect *a1-a0* from the awareness element on the mental state. It also captures the duration of time t_{a1}.

Variable *D* captures the effect *d1-d0* from the habit element and the duration t_{d1}.

Variable *C* captures the effect *c1-c0* from the self-control element and the duration t_{c1}.

Variable *R* captures the effect *r1-r0* from the rational element and the duration t_{r1}.

Probability *p* represents the chance that an element *{e}* of row S_i is not equal to an element *{e}* of column D_i.

The differences between the mental supply and demand, row S_i – column D_i, are:

$S_i - D_i$	*{0,d,c,r}*	*{1,0, c,0}*	*{1,0, c,1}*	*{1,1,0,0}*	*{1,1,0,1}*	*{1,1,1,0}*	*{1,1,1,1}*
{0,d,c,r}	0	-A,-pC	-A,-pC,-R	-A,-D	-A,-D,-R	-A,-D,-C	-A,-D,-C,-R
{1,0, c,0}	A,pC	0	-R	-D,pC	-D,pC,-R	-D,-pC	-D,-pC,-R,
{1,0, c,1}	A,pC,R	R	0	-D,pC,R	-D,pC	-D,-pC,R	-D,-pC
{1,1,0,0}	A,D	D,-pC	D,-pC,-R	0	-R	-C	-C,-R
{1,1,0,1}	A,D,R	D,-pC,R	D,-pC	R	0	-C,R	-C
{1,1,1,0}	A,D,C	D,pC	D,pC,-R	C	C,-R	0	-R
{1,1,1,1}	A,D,C,R	D,pC,R	D,pC	C,R	C	R	0

Illustration 4

From the above, we propose the following two necessary reaction conditions:

Condition R1 ***(In Time)*****:** $T \leq s_{ij}$

Condition R2 ***(Matching*** or ***Sufficient Mental Supply)*****:** $S_i \geq D_i$

That is, the reaction has to be in time and the mental state has to match with the required demand level. We use the term matching or sufficient mental supply to represent the quality and quantity compatibilities between the mental state supply and demand. Unfortunately, observations show that these conditions are much easier to be satisfied in the paper than in reality. Next, we use the existing framework to explore the flexibilities of the above conditions and aim to find the solution.

IV. The Optimal Reaction Strategy

At this point, let us summarize and discuss all the relevant components of the model.

Storyline: The individual is reacting to the activity *h* and encounters the event *i*. The event *i* is in the *extremely impulsive setting* as it meets the three **EIS conditions** defined in Definition 2: EIS1 (Snapshot), EIS2 (Seemingly Irrelevant), and EIS3 (Seemingly Insignificant). The event *i* is followed by the event *j* which is defined similarly.

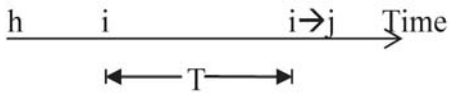


Illustration 5

The above illustrates the sequencing of the story. We posit that the individual has the mental state supply, S_i, and the event *i* calls for the mental state demand D_i. The

supply S_i is determined by the mental state formation processes while the demand D_i is exogenous to the model.

The variable T represents the total time to form the supply S_i and react to the demand D_i. The speed of change from the event i to the event j is represented by the variable s_{ij}. The individual reacts to the event i when the supply is determined in time. This is shown in Condition R1, $T \leq s_{ij}$.

During the mental state formation processes, the event i is checked against the predetermined set $\ddot{I}$ to generate each element of the supply $S_i = \{a,d,c,r\}_i$. The matching of the states S_i and D_i determines the reaction to the event i. The individual reaction is carried out when he has sufficient mental supply. This is captured in Condition R2, $S_i \geq D_i$.

We note the two opposing forces of the model: Condition EIS1 implies the duration $T > s_{ij}$ as the usual intuitive reaction; while Condition EIS2 and EIS3 suggest the set $\ddot{I} = \{\ \}$ as the habitual information set. To align the individual's reaction with his objective, we suggest two counterintuitive conditions: $T \leq s_{ij}$ and $S_i \geq D_i$ or, equivalently, $\ddot{I} = \{i_a, i_d, i_c, i_r\}$. Referring to Illustration 1, basically our aim is to expand the self-control scope and minimize the EIS area.

Now we have the storyline and the components of the model, let us analyze the possible reactions of the individual. In a very fine activity-time scale, the individual may; react to the activity h, react to the activity i, or react to neither the activity h nor the activity i. However, in this tense situation, many unknown variables are present and the reaction is not guaranteed to be done in time. That is, the duration of time T might be longer than the point which the activity i turns to the activity j. In addition, we are in the scope of the bounded rationality where the two decision systems, rational and intuition, compete and complement each other. All these facts support random results. So sometimes we see the individual reacts to the activity h, sometimes to the activity i, and other times he simply gets confused.

To demystify this situation, we analyze the related factors. First, we need to know more about the two activities. Chances are: both are the key activities, one of these two is the key activity, and none is the key activity. That is, $h \in \boldsymbol{h}^+$ or $h \notin \boldsymbol{h}^+$ and $i \in \boldsymbol{i}^+$ or $i \notin \boldsymbol{i}^+$.

In the same line, looking at the mental supply and demand for the activities h and i, it can be that the supply is sufficient for both, for one, or for none. So, $S_h \geq D_h$ or $S_h < D_h$ and $S_i \geq D_i$ or $S_i < D_i$.

To complete the permutation, we also have to compare the utility of the output H' and the one of the output I'. As the two values $U(H')$ and $U(I')$ are determined from the self-control stage; at this point, the individual has a clear preference. It is either $U(H') > U(I')$ or $U(H') < U(I')$. All he has to do is to form the mental supply to match with the mental demand.

Before we propose reaction strategies, we need the following assumption:

Assumption 2 ***(Full Information):*** At the time of reacting to the activity h and encountering with the activity i, the individual has full information and full conscience of these three issues:

(1) ***Right Information on Matching Variables:*** The full information on S_h, D_h, S_i, D_i, H, I, $U(H')$, and $U(I')$.

(2) ***Right Mind-set:*** The individual is fully conscious of the situation, alert, and prepared to react. He devotes his mental supply to select the activity and reacts to it. This ensures the matching of the mental supply and the demand according to Reaction Condition R2.

(3) ***Right Reaction and Right Time:*** From Reaction Condition R1, this assumption says that the individual plans and reacts following the reaction strategies in the forthcoming proposition. By doing that, the reaction time is also reduced to the minimum and Condition R1 is met, so $T_i < s_{ij}$.

In short, Assumption 2 requires that the information set takes the form $\ddot{I} = \{i_a, i_d, i_c, i_r\}$ which yields the mental supply $S_i = \{a1, d1, c1, r1\}_i$ and the minimum possible reaction time T_i.

Here, we analyze the assumption and justify that they are plausible. Note that they are needed only for the concerned snapshot period of time.

First, let us check Assumption 2(1) element by element: The variable S_h stands for the mental supply of the activity h, $\{a,d,c,r\}_h$. From the storyline, the supply S_h represents the concentration on the subject being studied. It includes awareness, determination, controlled effort and mental processes to formulate the required knowledge. To react optimally as per the forthcoming proposition, the individual must have the conscience of his current mental supply for the activity h. In the real world, we usually observe that the awareness of the supply S_h is in place for many important activities, e.g. job interview, a test-drive session. Hence, it can be argued that the assumption is realistic when the activity is deemed important.

The demand D_h captures the required mental supply to react to the activity h. It is activity-specific and exogenous to the model. We refer to Illustration 4 for matching results. This assumption says that the individual has full knowledge of the demand D_h. In fact, the knowledge required is merely the relative value of the supply S_h and the demand D_h. That is, while reading a chapter in a book, the individual knows how much he needs to concentrate and whether he has enough concentration to do it.

The supply S_i and the demand D_i could be interpreted similarly. Practically, the individual determines them from past experiences in combination with his forecast for the similar activities.

The mental supply bundle H consists of sub-activities $\boldsymbol{h^+}$, e.g. to understand a chapter in a book, one has to open the correct page, look at the words, retrieve the meaning of each word, think, analyze, and form the understanding. The assumption says that the individual has the knowledge of each element of the set $\boldsymbol{h^+}$ and he knows whether any given activity is a member of the set $\boldsymbol{h^+}$ or the set $\boldsymbol{h^-}$. This assumption is in line with real situations as the individual usually knows relevant steps or actions for certain activities. He also knows relevant impediments of each step.

The bundle I is defined in a similar way as the bundle H except that it includes the sub-activities of the interrupting activity, e.g. when the bundle H represents studying a chapter in a book, the bundle I is daydreaming about a vacation. So, its members are the sub-activities of daydreaming.

The values $U(H')$ and $U(I')$ represent the utility values of the output H' and I' respectively. We assume that they are determined by the individual in the self-control stage, so in the extremely impulsive setting he already has this knowledge. He knows whether he prefers the output H' or the output I'. Similar to the case of supply and demand, only the knowledge of the relative level of the value $U(H')$ and $U(I')$ suffices. From the continuing example, the individual manages to follow his plan and comes to the library to study. He decides already that he has to study. Here, the assumption says that such preference is aware at the time he is distracted by the urge to daydream.

A note to differentiate the output in the self-control stage, I'_{sc}, and the one in the extremely impulsive setting, I', might make it clearer here. The first one is out of our scope and we only refer to the second one. When the individual walks to the library, a friend invites him to a party. The decision between the two choices is in the self-control stage as the party activity is clearly distracting, relevant, and significant. Because of this, it does not meet the conditions of the extremely impulsive setting. Right there, however, when he decides that from that moment on for the coming hours the preferred activity is studying, he fixes his preferred task. So, we take it that the value $U(H')$ is the highest among the possible options, i.e. $U(H') > U(I'_{sc})$.

The output I' of our focus is daydreaming. In fact, the individual usually does not consider it worth choosing at the time he makes the above decision in the self-control stage. Going to the party is much more tempting than the brief moment of daydreaming while studying. In general, the output of the impulsive activities is normally irrelevant and insignificant, so it is less preferred. Hence, we argue that the assumption on relative preference between the value $U(H')$ and $U(I')$ is realistic.

Assumption 2(2) deals with the appropriate state of mind of the individual in the storyline at the time when he reacts. This ensures that the individual is sufficiently alert, conscious of the related elements in Assumption 2(1) and the related options in Assumption 2(3), and ready to react and allocate his mental supply to either the activity h or the activity i. Assumption 2(2) neither violates Condition EIS2 (Seemingly Irrelevant) nor Condition EIS3 (Seemingly Insignificant) even if it might initially seem so. In reality, we see Assumption 2(2) comes into play in different intensity. With its full force, it violates Conditions EIS2 and EIS3. Then there is no more EIS and all falls into the scope of self-control. Here, the assumption only calls for a moderate level in a way that the individual has sufficient conscience to know that however insignificant and irrelevant the activity seems, it is significant and relevant. We argue that the assumption is realistic as we observe that many individuals concentrate more and get less distracted when they are aware that they work on important tasks.

Assumption 2(3) concerns two issues: the right reaction and the right time. To see if the right reaction part is realistic, we postpone this until the proof of the forthcoming proposition. On the right time, we argue that the total processing and reaction time can be saved from mental preparation, alert conscience, and planned reaction.

Overall, Assumption 2 ensures that the individual has the right knowledge regarding the situation at hand and is sufficiently alert so that he can evaluate the situation and react optimally.

Grounded by Assumption 2 and from Definition 3, we are ready to propose the optimal reaction strategies:

Proposition ***(Reaction Strategies in the Extremely Impulsive Setting)*:**

a) When there is one key activity, respond to the key activity.
b) When there are two key activities or no key activity and the total mental supply is available for one activity, respond to the activity with the matched supply.
c) When there are two key activities or no key activity and the total mental supply is available for both activities or not available for any, respond to the activity which leads to higher utility.

To show the above proposition, we consider all the possible cases:

h	i	S_h vs. D_h	S_i vs. D_i	$U(H')$ vs. $U(I')$	Strategy	Reason of choosing h or i
$h \in \boldsymbol{h}^+$	$i \in \boldsymbol{i}^+$	$\geq$	$\geq$	$>$	c	h, as $U(H') > U(I')$.
$h \in \boldsymbol{h}^+$	$i \in \boldsymbol{i}^+$	$\geq$	$\geq$	$<$	c	i, as $U(H') < U(I')$.
$h \in \boldsymbol{h}^+$	$i \in \boldsymbol{i}^+$	$<$	$\geq$	$>$	b	i, as $S_h < D_h$.
$h \in \boldsymbol{h}^+$	$i \in \boldsymbol{i}^+$	$<$	$\geq$	$<$	b	i, as $S_h < D_h$.
$h \in \boldsymbol{h}^+$	$i \in \boldsymbol{i}^+$	$\geq$	$<$	$>$	b	h, as $S_i < D_i$.
$h \in \boldsymbol{h}^+$	$i \in \boldsymbol{i}^+$	$\geq$	$<$	$<$	b	h, as $S_i < D_i$.
$h \in \boldsymbol{h}^+$	$i \in \boldsymbol{i}^+$	$<$	$<$	$>$	c	h, as $U(H') > U(I')$.
$h \in \boldsymbol{h}^+$	$i \in \boldsymbol{i}^+$	$<$	$<$	$<$	c	i, as $U(H') < U(I')$.
$h \in \boldsymbol{h}^+$	$i \notin \boldsymbol{i}^+$	$\geq$	$\geq$	$>$	a	h, as h is the key activity.
$h \in \boldsymbol{h}^+$	$i \notin \boldsymbol{i}^+$	$\geq$	$\geq$	$<$	a	h, as h is the key activity.
$h \in \boldsymbol{h}^+$	$i \notin \boldsymbol{i}^+$	$<$	$\geq$	$>$	a	h, as h is the key activity.
$h \in \boldsymbol{h}^+$	$i \notin \boldsymbol{i}^+$	$<$	$\geq$	$<$	a	h, as h is the key activity.
$h \in \boldsymbol{h}^+$	$i \notin \boldsymbol{i}^+$	$\geq$	$<$	$>$	a	h, as h is the key activity.
$h \in \boldsymbol{h}^+$	$i \notin \boldsymbol{i}^+$	$\geq$	$<$	$<$	a	h, as h is the key activity.
$h \in \boldsymbol{h}^+$	$i \notin \boldsymbol{i}^+$	$<$	$<$	$>$	a	h, as h is the key activity.
$h \in \boldsymbol{h}^+$	$i \notin \boldsymbol{i}^+$	$<$	$<$	$<$	a	h, as h is the key activity.
$h \notin \boldsymbol{h}^+$	$i \in \boldsymbol{i}^+$	$\geq$	$\geq$	$>$	a	i, as i is the key activity.

h	i	S_h vs. D_h	S_i vs. D_i	$U(H')$ vs. $U(I')$	Strategy	Reason of choosing h or i
$h \in \mathbf{h}^+$	$i \notin \mathbf{i}^+$	$\geq$	$\geq$	$<$	a	i, as i is the key activity.
$h \in \mathbf{h}^+$	$i \notin \mathbf{i}^+$	$<$	$\geq$	$>$	a	i, as i is the key activity.
$h \in \mathbf{h}^+$	$i \notin \mathbf{i}^+$	$<$	$\geq$	$<$	a	i, as i is the key activity.
$h \in \mathbf{h}^+$	$i \notin \mathbf{i}^+$	$\geq$	$<$	$>$	a	i, as i is the key activity.
$h \in \mathbf{h}^+$	$i \notin \mathbf{i}^+$	$\geq$	$<$	$<$	a	i, as i is the key activity.
$h \in \mathbf{h}^+$	$i \notin \mathbf{i}^+$	$<$	$<$	$>$	a	i, as i is the key activity.
$h \notin \mathbf{h}^+$	$i \in \mathbf{i}^+$	$<$	$<$	$<$	a	i, as i is the key activity.
$h \notin \mathbf{h}^+$	$i \in \mathbf{i}^+$	$\geq$	$\geq$	$>$	c	h, as $U(H') > U(I')$.
$h \notin \mathbf{h}^+$	$i \in \mathbf{i}^+$	$\geq$	$\geq$	$<$	c	i, as $U(H') < U(I')$.
$h \notin \mathbf{h}^+$	$i \in \mathbf{i}^+$	$<$	$\geq$	$>$	b	i, as $S_h < D_h$.
$h \notin \mathbf{h}^+$	$i \in \mathbf{i}^+$	$<$	$\geq$	$<$	b	i, as $S_h < D_h$.
$h \notin \mathbf{h}^+$	$i \in \mathbf{i}^+$	$\geq$	$<$	$>$	b	h, as $S_i < D_i$.
$h \notin \mathbf{h}^+$	$i \in \mathbf{i}^+$	$\geq$	$<$	$<$	b	h, as $S_i < D_i$.
$h \notin \mathbf{h}^+$	$i \in \mathbf{i}^+$	$<$	$<$	$>$	c	h, as $U(H') > U(I')$.
$h \notin \mathbf{h}^+$	$i \notin \mathbf{i}^+$	$<$	$<$	$<$	c	i, as $U(H') < U(I')$.

Illustration 6

We justify the three strategies:

Strategy a: One key-activity.

Consider the case of $h \in \mathbf{h}^+$, $i \notin \mathbf{i}^+$; $S_h \geq D_h$; $S_i \geq D_i$; $U(H') > U(I')$.

Proof: As the activity h is a member of the bundle H, reacting to the activity h contributes to the completion of the bundle H. Likewise, the activity i is not a member of the bundle I, reacting to the activity i does not contribute to the completion of the bundle I.

Logically, the value $U(H') > 0$ and so reacting to the activity h contributes to an increase in utility through the output H' while reacting to the activity i does not. It is then better off to react to the activity h. Q.E.D.

Strategy b: Two key activities or no key activity when the total mental supply is available for one activity.

Consider the case of $h \in \mathbf{h}^+$, $i \notin \mathbf{i}^+$; $S_h \geq D_h$; $S_i < D_i$; $U(H') < U(I')$.

Proof: The activity h is a member of the bundle H, reacting to the activity h contributes to the completion of the bundle H. Likewise, the activity i is a member of the bundle I, reacting to the activity i contributes to the completion of the bundle I.

From the value $U(H') < U(I')$, reacting to the activity i would have yielded higher utility value. However, the given mental state condition $S_i < D_i$ signifies an under-supplied case (one of the states in the upper-right corner of Illustration 4).

This violates Matching Condition (Condition R2). Thus, it is unfeasible to react to the activity i.

On the other hand, as the mental state condition is $S_h \geq D_h$, reacting to the activity h is feasible as the mental supply is sufficient.

As the value $U(H')$ is positive, reacting to the activity h contributes to an increase in utility through the output H'. It is then better off to react to the activity h. Q.E.D.

Strategy c: Two key activities or no key activity when the total mental supply is available for both activities or not available for any.

Consider the case of $h \in \boldsymbol{h}^+$, $i \in \boldsymbol{i}^+$; $S_h \geq D_h$; $S_i \geq D_i$; $U(H') > U(I')$.

Proof: The activity h is a member of the bundle H, reacting to the activity h contributes to the completion of the bundle H. Likewise, the activity i is a member of the bundle I, reacting to the activity i contributes to the completion of the bundle I.

As the given mental state condition is $S_h \geq D_h$, reacting to the activity h is feasible as the mental supply is sufficient. Likewise, with the condition $S_i \geq D_i$, reacting to the activity i also matches the mental supply.

However, as the value $U(H')$ is higher than the value $U(I')$, reacting to the activity h contributes to a higher increase in utility through the output H'. It is then better off to react to the activity h. Q.E.D.

Conclusion

People often make everyday decisions based on their intuition. A large number of experiments in Neuroeconomics and Behavioral Economics draw this conclusion without providing explanations on the reaction-generating processes. These intuitive reactions are efficient and appropriate in many situations. However, when the issue at stake concerns immediate rewards, intuitive reactions usually lead to suboptimal results. In fact, these reaction patterns may breed bad habits and act as endogenous constraints to one's making an optimal choice. They can eventually cause major undesirable consequences.

This paper offers a model which explains intuitive reaction processes and bridges the literature on Self-Control and Bounded Rationality. It aims to tackle the abovementioned impulsive reactions which lead to negative results. The model explains the mental supply formation steps at the time reactions take place. The reactions come from compatibility between the controllable mental supply and the given mental demand. We then propose optimal reaction strategies of which validity rests on the willingness and determination of people to control their mental supply. The paper suggests that, by bringing conscience and self-control into people's intuitive reactions, people's endogenous constraints can be removed and their utilities enhanced.

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