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I. Introduction

This is a symposium report of "Science of impulsiveness", which was held on 22nd, December, 2007, at Keio University, Tokyo. I organized the symposium and participated in it as a chairperson. In the first section of this report, I describe my strategies for the exchange of ideas and discussions between the many academic fields concerned with impulsiveness. Then, participants in the symposium summarize their works in the order as shown below.

Schedule

10:15 Shigeru Watanabe (Leader of Center for Advanced Research on Logic and Sensibility, Keio University): "Opening remarks"
10:20 Takayuki Sakagami (Department of Psychology, Keio University): "Introduction and announcement from the chairperson"
10:30 Ryo Kurashima and Shigeru Watanabe (Department of Psychology, Keio University): "Impulsive and self-control choice depending on deprivation level"
11:00 Masato Ito (Osaka City University): “Why do people give way to the temptation of temporary pleasures?: A functional approach to impulsiveness”
11:30 Toshiya Matsushima, Hidetoshi Amita, Shouhei Matsunami, and Ai Kawamori (Laboratory of Animal Behavior and Intelligence, Department of Biology, Faculty of Science, Hokkaido University): “Control of impulsiveness and the optimal foraging behavior”

12:00 Lunch

13:30 Daisuke Saeki (Department of Literature, Osaka City University): “Impulsiveness from the viewpoint of temporal discounting”
14:00 Taiki Takahashi (Department of Cognitive and Behavioral Science, University of Tokyo): “Neuroeconomics of impulsivity and decision under risk”
14:30 Taku Ishii (Center for Advanced Research on Logic and Sensibility (CARLS), Keio University): “Temporal discounting and prospective timing: Is a value theory valid?”

15:00 Coffee break

15:15 Mai Yamaguchi (Graduated School of Psychology, Faculty of Litter, Doshisha University): “Impulsive behavior from emotion: Theory and actual research”
15:45 Takashi Kusumi (Graduate school of Education, Kyoto University): “The impulsive decision style and cognitive-affective decision processes”
16:15 Shinji Okazaki (Institute of Disability Sciences, University of Tsukuba): “Assessment of impulsivity in children with developmental disabilities”

16:45 General discussion

17:15 Shigeru Watanabe: “Concluding remarks”

Strategies for the exchange of ideas

Impulsiveness is one of the important issues in the behavioral, social and medical sciences. Impulsiveness produces a wide range of troublesome
outcomes that are not confined to personal issues, but are also related to social and global-scale problems. For example, Mazur (2006) cited “Tragedy of commons” by Hardin (1968) in the final section of his textbook “Learning and behavior”, and he proposed that we as human beings should learn to control our impulsiveness, for the sake of our own futures. Many scientists have given cautions about the possibility that our communities could meet with disastrous crises, such as increasing temperature, explosive population growth, depletion of food and energy resources, and so forth. However, people have neglected them and have not taken effective action against impulsiveness.

One of the purposes of our Global COE (Center for Advanced Research on Logic and Sensibility, Keio University) is to construct a bridge between two modes of academic activity: Logic and sensibility. In the context of impulsiveness, we know that these issues are strongly related to temporal discounting, which is in turn connected with economic analysis of values. Traditional economic analysis using the logic of rational choice, such as subjective utility theory, has proposed the exponential discounting function as an explanation of temporal discounting. From my point of view, this economic analysis has been strongly driven by logic and mathematics.

On the other hand, behavioral studies have proposed an alternative, the hyperbolic discounting function. One of the reasons for using this function is that it appears to better fit human and animal experimental data, as compared to the exponential function. A more important reason is that the hyperbolic function allows us to theorize about self-controlled behavior. A simple form of the hyperbolic function can explain why people sometimes prefer a more immediate and smaller reward to a more remote and larger reward (or reinforcer). Thus, researchers in this field have insisted on the descriptive superiority of this function, and have proposed a mechanism of impulsiveness, a concept that was previously discussed only from emotional and clinical frameworks.

This symposium aims to make a bridge between ‘logic’ (rationality) and ‘sensibility’ (emotion). I do not know whether we can make any strong and/or realistic bridges between the ‘logic’ side and the ‘sense’ side. However, we can review the systematic presentations of various fields, including neuroscience, neuroeconomics, biological psychology, behavior analysis, emotion psychology, social psychology, and developmental psychology, and an effective exchange of ideas among these disciplines should brew and
stimulate good new ideas.

The development of cooperative research on impulsiveness might be based on some strategies for the exchange of ideas. First, we may apply the functions or formal statements that are well-established in other fields to our own. For example, behavioral researchers have tried to apply the exponential function from economic science to their own experimental data. This application will not only expand their applicability but will also create new fundamental problems caused by mismatches.

Second, we may appreciate and utilize several anomalies and paradoxical findings from the various fields. For example, many anomalies were reported in intertemporal choice data, such as time inconsistency, delay effects, interval effects, magnitude effects, and so on (Read, 2004). It is not difficult to find such anomalies in other fields as well, i.e., behavioral ecology and human decision making. We will learn about these phenomena from the work of other disciplines and look for similar anomalies in our own field.

Third, we will attend to the methods, especially to those procedures that have been frequently used in other scientific areas. Because these procedures may have inherent properties and unique histories in their own scientific disciplines, we may not be able to easily utilize and apply them in our own paradigm. However, it is worth trying this strategy, in that it may inform us regarding unexpected findings or limits of our own traditional methodology. For example, some researchers in behavioral decision making have used experimental economic procedures such as the second price auction, and have discussed their superiority.

I believe that the bridge between ‘logic’ and ‘sensibility’ poles will be constructed firmly, if researchers in various fields can exchange their ideas and have discussions according to these three strategies.

References


II. Impulsive and self-control choice depending on deprivation level

Ryo Kurashima and Shigeru Watanabe

Department of Psychology, Keio University

1. Introduction

Organisms behave according to their states. For example, when rats are allowed to choose water or food, hungry rats may choose food, whereas thirsty rats may choose water.

Kupferman and Schwartz (1997) stated that behavior reflects what a person needs or wants. Such needs or wants can be described as motivation. Motivation endows an organism's behavior with significance. When animals are hungry, they as organisms increase feeding behaviors. Like thirst induces drinking behavior, organisms behave via innate motivation.

Delayed choice is the choose between short interval but small reward, and long interval but large reward. Short interval but small reward is called an S-S reward, whereas long interval but large reward is called an L-L reward. Impulsive choice is the selection of an S-S reward in preference to an L-L reward, whereas self-control is the choice of an L-L reward in preference to an S-S reward.

In our lives, immediate rewards may not always be the best choice. Instead, we often encounter situations in which we need to choose either S-S rewards or L-L rewards. One of the well-known examples is a choice between 5 dollars that you can get now and 20 dollars that you can get 2 days later. There are many studies that have examined how organisms make delayed choices. Instrumental conditioning paradigms using animals such as rats and pigeons provide a useful research method to determine the factors that affect delayed choice, such as delay, reward, and reward quantity.

Our question is as follows: When motivation changes, does delayed choice also change? For example, if you are tired, which option do you choose: Sleeping now on the desk and working after a short sleep, or working now and sleeping more deeply after finishing your work? In human studies, motivation changes delayed choice. It is therefore important to study the
Bradshaw and Szabadi (1992) demonstrated counterintuitive results in a study of temporal discounting and impulsive choice in rats. They manipulated rats' body weights at two different levels: 80% and 90% of their free feeding body weights. Rats chose the L-L reward more frequently than the S-S reward, suggesting that hungry rats became less impulsive. Difference in deprivation levels changed rats' delayed choice behavior.

The main purpose of our experiments was to investigate changes in rats' choice between an S-S reward and an L-L reward by controlling their deprivation levels. In Experiment 1, like in previous studies, we controlled deprivation level based on rats' body weights. On the other hand, in Experiment 2, deprivation levels were manipulated by controlling feeding times prior to experimental session choices made by sated rats. Furthermore, in Experiment 2, we investigated relations between inter-trial interval and delayed choice, by fixing inter-trial interval. Fixing inter-trial interval would change the duration of one session. Therefore, if subjects make their choices according to the total duration of one session, their choices should change.

2. Method

2.1. Subjects

Subjects were male Wister rats. They were divided into two groups. In Experiment 1, eleven rats were maintained at 80% body weight, and the other ten rats were maintained at 90% of their ad-lib body weights. In Experiment 2, eight rats were food-deprived for 20-22 hrs prior to each experimental session, so that their feeding time was restricted for 2-4 hours per day right after the session. The other eight rats were food-deprived for 2-2.5 hours prior to each experimental session, so that they had access to food nearly all day, meaning that these rats were sated. Each subject was given daily food at the home cage, just after each subject finished the daily experiment.

2.2. Apparatus

The experimental apparatus was an operant box with two retractable levers. A food tray was placed in the front panel, and a pellet was dropped from a dispenser. A houselight on the back wall provided general illumination during
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2.3. Procedure

2.3.1 Experiment 1

The procedure was an adjusting delay schedule. Delays for larger rewards were adjusted based on subjects' own choices. Responses to lever A initiated a delay of 2 seconds followed by delivery of 1 pellet, whereas responses to lever B initiated variable delays (delays of lever B; dB) followed by delivery of 2 pellets. Lever position was counterbalanced across subjects. Each session consisted of 8 blocks of 4 trials. The first 2 trials in each block were forced choice trials. In these forced-choice trials, only a lever was presented and responses to the lever provided either a pellet after a shorter delay or two pellets after a longer delay. Following these 2 trials were free-choice trials. In these free-choice trials, both levers were presented so that subjects could choose either one. When subjects failed to respond in 10 seconds, the response lever was retraced and the trial was counted as an omission.

Variable delay dB depended on a subject’s choice in a previous free choice trial. If subjects chose lever B twice in a block, dB was prolonged 20% in the next block. When subjects did not choose lever B, dB was shortened 20% in the next block. When the subject chose lever B once in a block, dB remained the same in the next block. The dB was set to 2 seconds at the beginning of the first session. dB for the beginning of the next session was set to the mean dB of the last 4 blocks. Maximum delay was set to 60 seconds, and minimum delay was set to 2 seconds.

We set three criteria to obtain adjusting delay. First, neither the highest nor the lowest was the adjusted delay in any blocks over the last 6 sessions. Second, the mean delay across the last 3 sessions was not the highest or the lowest 3-session mean of the condition. Third, the mean delay of the last 3 sessions was not different from the mean of the preceding 3 sessions by more than 10% (whichever was larger).

When subjects’ behavior met these three criteria, mean dB in the final three sessions was considered as an adjusting delay for the subjects. Mean adjusting delay between the two groups was compared by t-test.
2.3.2 Experiment 2
In experiment 2, an adjusting-delay schedule was also used, and the main schedule was same as Experiment 1. However, the inter-trial interval was fixed at 54.7 sec. For the first 60 sessions, the procedure was the same as in Exp.1 (normal condition). After the 61st session, the inter-trial interval was fixed (fixed condition). In the normal condition, each subject’s adjusting delay (which met the three criteria by the 60th session) was used in statistical analysis. In the fixed condition, which we are still working on, each subject’s adjusting delay (which met the three criteria by the 90th session) was used in statistical analysis.

3. Results

3.1. Experiment 1
Mean adjusting delay was longer in the 80% group than in the 90% group. A t-test revealed that the difference was statistically significant (t (16)=7.38, p < 0.01). Figure 1 shows the mean adjusting delay for the two groups.

3.2. Experiment 2
In both normal and fixed conditions, mean adjusting delay in the 22-24 hrs deprivation group was significantly longer than in the 2-2.5 hrs deprivation group. However, there were no differences observed between the two
4. SCIENCE OF IMPULSIVENESS

4.1. Choice difference dependent on deprivation level

Results from experiment 1 suggest that when body weight is low, rats become more self-controlled. Conversely, when body weight is high, rats become more impulsive. These results are consistent with those of previous studies (Bradshaw & Szabadi, 1992, Wogar et al, 1992, Ho et al, 1997).

The results of Experiment 2 suggest that sated rats become more impulsive. In contrast, when the feeding time is short, rats become more self-controlled.

From these results, we can conclude that deprivation level changes rats’ choice between an S-S reward and an L-L reward. On the adjusting delay schedule, rats become more impulsive when they become less hungry.

Hunger is one of the motivational factors that affects an organism’s behavior, but other motivational factors, such as thirst, tiredness, and need for sleep may also affect delayed choices. Therefore, we should study other methods to get...
subjects to change their motivation. Dickinson (1994) said that Pavlovian conditioning endows the conditional stimuli with motivational properties. By using both Pavlovian conditioning and instrumental conditioning, delayed choice should be changed by conditional stimuli. If a conditional stimulus endows subject’s delayed choices with motivation properties, subjects may choose L-L rewards frequently, at least in the case of delayed choice with conditional stimuli. If this is true, we can say that not only does hunger makes rats more self-controlled, but higher motivational levels also make rats more self-controlled.

4.2. Effect of fixed inter-trial interval

The results of Experiment 2 show that fixing inter-trial interval does not appreciably affect rats’ choices. These choices seem to depend largely on the delay between decision-making and presentation of rewards. Adjusting the delay schedule we used in Experiment 1 and the normal condition in Experiment 2 did not change session time, but the fixed condition in Experiment 2 changed session time via each subject’s choices. This may mean that subjects did not decide choice depending on experimental context, because differences in session duration did not affect subjects’ choices. More studies of context and delayed choice are required.

References


III. Why do people give way to the temptation of temporary pleasures?: A functional approach to impulsiveness

Masato Ito

Osaka City University

People often give in to the temptation of temporary pleasures, such as a drink or a cigarette; that is, people show impulsiveness. Impulsiveness is a serious problem faced by many (e.g., people who are dependent on substances such as alcohol). Although there are a variety of approaches to the study of impulsiveness, a functional approach has proven to be a useful tool. In this approach, impulsiveness can be seen as a choice behavior that varies along a continuum from an impulsive choice to a self-controlled choice, one relevant to a variety of situations, including both healthy and unhealthy situations. In the standard choice procedure, preference for an immediate small reinforcer over a delayed larger reinforcer has been called impulsiveness. Impulsive choice behavior can be described by the following generalized matching law:

$$\frac{R_1}{R_2} = k \left( \frac{A_1}{A_2} \right)^{sa} \left( \frac{D_1}{D_2} \right)^{sd}$$

where $A$ is reinforcer amount, $D$ is delay to reinforcement, $R$ is the number of responses to that alternative, and $k$, $sa$, and $sd$ are empirical constants. The parameters $sa$ and $sd$ represent the sensitivity to variations in reinforcer amount and delay, respectively. According to the generalized matching law, the ratio of reinforcer amount and delay (i.e., $A/D$) is taken to represent a reinforcing value for each alternative.

In contrast, a different version of the generalized matching law (molar maximization) holds that the reinforcing value for each alternative is based on the total time ($T$) rather than prereinforcer delay ($D$) alone; total time is defined as the sum of the choice phase duration, prereinforcer delay, reinforcer access period, and postreinforcer delay (i.e., timeout period). The ratio of reinforcer amount and total time (i.e., $A/T$) is taken to represent a reinforcing value for each alternative.
value for each alternative, according to molar maximization. In either view, reinforcement density is supposed to determine preference in a self-control choice situation. The ratio of reinforcer amount and delay (A/D) is referred to as local reinforcement density (i.e., LRD), whereas the ratio of reinforcer amount and total time (A/T) is referred to as overall reinforcement density (i.e., ORD). Therefore, these two different views are represented as the following generalized matching equations:

\[
\frac{R_i}{R_j} = k_{LRD} \left( \frac{LRD_i}{LRD_j} \right)^{S_{LRD}} \tag{2}
\]

\[
\frac{R_i}{R_j} = k_{ORD} \left( \frac{ORD_i}{ORD_j} \right)^{S_{ORD}} \tag{3}
\]

where \(k_{LRD}, k_{ORD}, S_{LRD}\) and \(S_{ORD}\) are empirical constants. The parameters \(S_{LRD}\) and \(S_{ORD}\) represent sensitivity to variations in reinforcement density. According to these reinforcement density models, participants should choose the alternative of high reinforcement density over that of low reinforcement density. Thus, impulsive choice is thought to be rational if the impulsive choice produces a greater reinforcement density than the self-control choice would produce.

Ito & Nakamura (1998) examined the applicability of these views to humans’ decisions in a self-control choice situation, where participants chose between immediate smaller reinforcers and delayed larger reinforcers. In Experiment 1, participants were exposed to three different pairs of reinforcer amounts and delays, and sensitivity to reinforcer amount and delay was determined based on the generalized matching law. In Experiment 2, participants chose between immediate smaller reinforcers and delayed larger reinforcers in five conditions, with and without timeout periods that followed a shorter delay, in which reinforcer amounts and delays were combined to make different predictions based on LRD or ORD. As shown in Figure 1, obtained choice proportions increased more systematically with increases in the ORD predictions than in the LRD predictions, although obtained choice proportions were more extreme than predicted from the ORD. Therefore, humans’ choices were qualitatively in accord with the predictions from the ORD.
These results reveal that humans' impulsive choices are rational rather than irrational, and are well described by the ORD, rather than by the LRD.

Reference


IV. Control of impulsiveness and the optimal foraging behavior

**Toshiya Matsushima, Hidetoshi Amita, Shouhei Matsunami, and Ai Kawamori**

Laboratory of Animal Behavior and Intelligence, Department of Biology, Faculty of Science, Hokkaido University

Do animals have mind? Do non-mammalian vertebrates, in particular, have mental processes similar to ours? Recent progresses in comparative (therefore,
inevitably, evolutionary) cognitive neuroscience suggest that there is a commonality between birds and us. A brief list of such studies includes those of object constancy in newly-hatched domestic chicks (Regolin & Vallortigara, 1995), episodic-like memory in food caching scrub jays (Clayton & Dickinson, 1998), and categorical discrimination of paintings by Picasso and Monet in pigeons (Watanabe et al., 1995). These similarities might have been shaped by common selection pressures, thus representing an analogy through convergent evolution. Alternatively, the brain-mind linkage could have been so tight that it was highly conserved through divergent evolution of amniotic vertebrates, leading to birds and mammals. The similarity should therefore represent genuine homology. In this report, we will review our recent experimental analyses of choice behavior in domestic chicks. Particular attention was paid to ecological background and the underlying neural mechanisms. Our results strongly suggest that the neural agents responsible for economical decisions about food rewards are highly conserved, thus favoring the possibility of mental homology.

1. Optimal foraging theory and profitability

Charnov (1976) pointed out that optimal foragers should have a certain level of impulsiveness. According to his pioneering theory (also see Stephens and Krebs (1986), or Alexander (1996) for further developments), animals maximize the long-term averaged gain rate through precise estimation of profitability of each food item. The profitability is given as a ratio of energetic gain available from one food item per unit handing time; the longer the handling time, the lower the profitability, with its gain being equal. In contrast to the matching theory of choices (Herrnstein 1997; Mazur 2002), however, the optimal forager must execute decisions according to the zero-one rule, so that the forager always chooses the better option regardless of the relative value of profitability. The challenge for neuroscience is to formulate the behavioral processes and the underlying neural mechanisms for computation of food profitability, so that the algorithm of decisions can be explicitly analyzed.
2. Neural substrates of anticipated food reward: Amount, delay and consumption cost are dissociable

As predicted, week-old domestic chicks made choices according to the anticipated profitability of food items, depending on the relative value. These decisions thus follow the matching law and deviate from the optimization view (see reviews by Matsushima et al. (2003, in press) for details). Chicks were trained to peck at a colored cue bead, each of which was associated with food (millet) of a fixed amount and delay time; e.g., the red bead was associated with 6 grains delivered after t-sec delay (t=0,1,2, or 3 sec), whereas the blue bead was associated with 1 grain of food delivered immediately (i.e., delay < 0.2 sec) (Izawa et al., 2003). In addition to the delay (or forced waiting time to food), chicks spent an additional few seconds just to consume the food (consumption time). The profitability is given by the amount of food divided by the sum of the delay and the consumption time.

A neural pathway involving the ventro-medial striatum (nucleus accumbens: NAc) has been shown to be responsible for the control of impulsiveness in profitability-based decisions. Actually, choices are not uniquely determined by food profitability. Instead, animals stress either the proximity (inverse of the sum of delay and consumption time) or the amount (energetic gain). In cases where the proximity is given priority, a small-but-immediate food item should be favored over a large-but-delayed food item, with their profitability being equal; such a choice is referred to as impulsive. In other cases where amount is given priority, the large food is always favored over the smaller alternative; such a choice is referred to as self-controlled. In other words, choices are characterized in terms of dependence on profitability as a primary factor, and secondarily by the stress on proximity.

Localized lesions to the bilateral NAc caused chicks to choose immediate food items significantly more frequently than the sham-operated control subjects, when the large food was delayed by 1-3 seconds. Choices based solely on the food amount (i.e., 6 grains vs 1 grain with the identical short delays) were not influenced (Izawa et al., 2003; Aoki et al., 2006a). The NAc lesions can thus be said to have made chicks impulsive. The NAc receives massive excitatory inputs from cortical analogues; for the issue of recent nomenclature reform on the avian “neocortical structures”, see Reiner et al. (2004).
Of these "cortical" regions is the arcopallium (Arc), which was initially and erroneously named the archistriatum, although the Arc is assumed to be functionally analogous to the association cortex (i.e., the parietal / prefrontal cortices in the mammalian brain). Lesions to the bilateral Arc caused chicks to choose the food item with a considerable consumption time significantly more frequently than the sham-operated controls, with their sensitivity to the delay being unchanged (Aoki et al., 2006b). The delay and consumption time were doubly dissociated, indicating that these two components of time are functionally separated. Furthermore, the lesions (either NAc or Arc) failed to shift chick choices based on the anticipated amount of food items; decisions based on food amount are thus also separable. In accord with this, neuronal recordings from the NAc and surrounding areas revealed distinct populations of neurons for food amount and delay. So far, we have failed to detect neurons that code profitability in an integrated manner (Yanagihara et al., 2001; Izawa et al., 2005).

3. Risk, competition and serotonin for controlling choices

Choices proved to be sensitive to contextual factors, such as risk and competition. Actually, chicks were risk-averse in the choices between two opposing feeders (Kawamori and Matsushima, unpublished). One feeder supplied food of a constant amount (5 grains of millet), while the other feeder supplied either no food or an amount twice as large (10 grains) at equal probability; note that these two feeders gave rise to equal profitability and the delay was also set to be identical. Chicks consistently chose the constant feeder, and a behavioral titration experiment revealed that the variable feeder was used just as much as a feeder that constantly supplied around 3 grains. Most probably, chick behaviors are organized so that null gain situations are carefully avoided. A max-min strategy might also be considered, in addition to optimality.

Competitive foraging during the course of training sessions also enhanced impulsiveness (Amita & Matsushima, unpublished). Typically, week-old chicks must be trained for 3-5 successive days (around 30 min x 1-2 sessions each day), until they reliably perform operant pecking responses in a responsive manner to food profitability. If chicks were housed in groups of 3 during the training sessions, they must share the job of pecking colored beads and must also share the resulting gain (namely 1 or 6 grains). Execution does not lead
to gain at the individual level under such competitive conditions. When trained in competition, chicks showed a higher level of impulsiveness during test sessions. Choices are therefore sensitive to developmental contexts.

Administration of an SSRI (a serotonin-selective reuptake inhibitor; fluvoxamine, courtesy of Meiji-Seika Co.) caused chicks to stay longer at the feeder, and the immediate gain rate was progressively decayed (Matsunami & Matsushima, unpublished). In birds, the SSRI also acts as an anti-psychotic, as its intra-peritoneal injection (20 mg / kg BW) suppressed the frequency of distress calls in social isolation, though spontaneous locomotor activity remained unchanged; the presumed anxiolytic effect was not a by-product caused by sedative action. It remains to be determined, however, if the SSRI injection also caused changes in risk sensitivity and impulsiveness.

These results strongly indicate that the week-old chicks of domestic chickens serve as an excellent model animal for the study of the neuro-cognitive bases of foraging-behavior decisions.

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V. Impulsiveness from the viewpoint of temporal discounting

Daisuke Saeki

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1. Temporal discounting

If you are told that you will receive next week the salary that you thought would be paid today, you feel discouraged. This discouragement can be due to temporal discounting, the decrease in the subjective value of rewards by a delay in receipt of the rewards (Green & Myerson, 1993; Rachlin, Raineri, & Cross, 1991). Temporal discounting has been studied mainly in the areas of economics and psychology. In these research areas, mathematical models of temporal discounting have been examined, along with factors that influence such discounting (Benzion, Rapoport, & Yagil, 1989; Green, Myerson, & McFadden, 1997; Myerson & Green, 1995; Rachlin et al., 1991). Because the rate of temporal discounting that is estimated by applying discounting functions to data can be thought to reflect degree of impulsiveness (Green & Myerson, 1993), specifying the mathematical model that can precisely describe temporal discounting then makes it possible to quantify degree of impulsiveness. In this paper, the question concerning the quantification of impulsiveness is discussed through an examination of mathematical models of temporal discounting, proposed in economics and psychology. Furthermore, some problems in behavioral economics and psychological studies of temporal
discounting are pointed out.

2. Mathematical models of temporal discounting

In economics, the exponential function expressed in Equation (1) has been traditionally used as a mathematical model of human temporal discounting:

\[ V = Ae^{-KD} \]  (1)

\( V \) is the subjective value of the delayed reward, \( A \) is the amount of the reward, \( D \) is the length of the delay to receipt of the reward, and \( k \) is a free parameter that describes degree of discounting. The exponential function derives temporal discounting, in which proportion of decrease in subjective value is constant as each unit of time passes (Kirby, 1997). This means that the function predicts that preference between delayed rewards must be invariant at every time point. Accordingly, the exponential function has been referred as the temporal discounting model of “rational decision makers”, whose preferences are consistent regardless of the time point at which they make a decision (Myerson & Green, 1995). Theoretical curves derived from Equation (1) are shown in Figure 1a.

On the other hand, in psychology, the hyperbolic function expressed in Equation (2) has been proposed as a mathematical model of temporal discounting that can describe the phenomenon in both human and nonhuman animals (Mazur, 1987; Rachlin et al., 1991; Richards, Mitchell, de Wit, & Seiden, 1997):

\[ V = \frac{A}{1 + kD} \]  (2)

The meanings of symbols are the same as in Equation (1). The hyperbolic function is different from the exponential function, in that the proportion of decrease in subjective value decreases as each unit of time passes. Theoretical curves derived from Equation (2) are shown in Figure 1b.

The exponential and hyperbolic functions make different preference predictions in self-control choice situations. In the self-control choice situation, participants choose between two alternatives: A smaller, immediate reward, and a larger, delayed reward. In this situation, preference for the former is
called as impulsiveness, whereas preference for the latter is called self-control (Logue, 1988). In the self-control choice situation, preference may switch from the larger, delayed reward to the smaller, immediate reward as time passes. This change in preference is called preference reversal (Green & Myerson, 1993). As the solid lines in Figure 2a and Figure 2b show, the hyperbolic function can describe this phenomenon (i.e., preference switches from the larger, delayed reward to the smaller, immediate reward, at the time point when the two curves cross), but the exponential function cannot describe this pattern. This fact suggests that the hyperbolic function more adequately fits the temporal discounting phenomenon than the exponential function.

However, as the dashed line in Figure 2a shows, if the discounting rate decreases as the reward amount increases, the exponential function can also describe the preference reversal (Green & Myerson, 1993; Kirby, 1997). Because many studies have revealed that this type of effect can occur in humans (e.g., Green et al., 1997; Kirby, 1997), it is not possible to examine the validity of the discounting function in terms of the predictability of the preference reversal phenomenon.

### 3. Empirical studies on temporal discounting

In economics and psychology, mathematical models of temporal discounting have been examined by comparing empirical data to the predictions derived...
from the models (Benzion et al., 1989; Loewenstein & Prelec, 1992; Rachlin et al., 1991). In economics, earlier studies of temporal discounting were largely theory-oriented. However, recently, empirical studies on temporal discounting have been carried out in the research area of “behavioral economics”. Typically, in empirical studies of temporal discounting, immediate reward amounts judged as subjectively equivalent to the delayed rewards are measured for several delay conditions in experiments or via questionnaires, and coefficients of determination are compared between mathematical models that are fitted to the equivalence points. Many studies report that the coefficients of determination are higher in the hyperbolic function than in the exponential function (e.g., Rachlin et al., 1991; Green et al., 1997; Kirby, 1997).

For example, Saeki and Ito (1998) measured (via questionnaires) hypothetical immediate monetary rewards equivalent to a hypothetical 100,000 yen, for delay conditions ranging from one month to 50 years. Figure 3 shows median equivalence points and best-fitting exponential and hyperbolic functions. The coefficient of determination was higher in the hyperbolic function (0.95) than in the exponential function (0.85). This fact indicates that the hyperbolic function provides a valid mathematical model of temporal discounting. Furthermore, previous studies reported that discounting rates are higher in drug-using participants than in nondrug-using participants (Madden, Petry, Badger, & Bickel, 1997), and were higher in smokers than in nonsmokers (Bickel, Odum, & Madden, 1999). These findings suggest that the discounting
rate is valid as an index of degree of impulsiveness.

However, some problems with empirical studies of temporal discounting can be pointed out. First, so far, empirical studies on human temporal discounting have used hypothetical choice situations (Rachlin et al., 1991), or choice situations where the rewards that participants chose are realized after the experiment concludes (Kirby, 1997). On the other hand, choice situations where participants experience the rewards by choosing between alternatives repeatedly has been rarely been used, although this type of choice situation has been commonly used in studies of the self-control choice (Navarick, 2004).

Second, both the exponential and hyperbolic functions assume a linear relationship between the reward amount and the subjective value. However, in economics and psychology, the relationship between these variables has often been assumed to be nonlinear (e.g., Loewenstein & Prelec, 1992; Stevens, 1959). Thus, a mathematical model that can describe a nonlinear relationship between the reward amount and the subjective value will be needed to measure discounting rate more precisely.

References


VI. Neuroeconomics of impulsivity and decision under risk

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1. Neuroeconomic studies on impulsivity and decision under risk

Intertemporal and probabilistic choice have drawn attention in behavioral economics, econophysics, and neuroeconomics, and these phenomena are strongly influenced by neurochemical modulations (Takahashi, 2008b). This affirms the importance of neuroeconomic investigations into intertemporal and probabilistic choice.

Let us first look at intertemporal choice. Consider the following intertemporal choice problems:

(A) Choose between (A.1) One cup of coffee now.
    (A.2) Two cups of coffee tomorrow.

(B) Choose between (B.1) One cup of coffee in one year.
    (B.2) Two cups of coffee in [one year plus one day].

Most people make the impulsive choice in problem (A) (i.e., choosing (A.1), displaying a preference for the small immediate reward), while the same subjects make the more patient choice in problem (B) (i.e., they choose (B.2), displaying a preference for the large delayed reward). The combination of these typical intertemporal choices is inconsistent, because the time-interval [between (A1) and (A2)] and the time-interval [between (B1) and (B2)] are the same (= 1 day). Most people’s intertemporal choice plan in example B will be reversed in example A, as the time of executing the planned action approaches the present.

Although several aspects of human and animal decision under risk processes have been well formulated with Kahneman and Tversky’s prospect theory and its modified versions, behavioral economic theories of intertemporal choice still have problems explaining observed anomalies (e.g., dynamic inconsistency). Contrary to the normative economic theory of intertemporal choice (i.e., exponential discounting), it has now been well established that
human and animal intertemporal choice behaviors are not rational (i.e., inconsistent). For this reason, recent economic theories of dynamic optimization and behavioral decision theories of intertemporal choice have adopted a hyperbolic discount model, rather than an exponential one. The hyperbolic discount model can explain a widely-observed tendency of human and animal intertemporal choice—a decreasing impatience. In other words, subjects overestimate their patience in the distant future, resulting in preference reversal as time passes. The preference reversal in hyperbolic discounting may explain various problematic behaviors by humans—loss of self-control, a failure in planned abstinence from addictive drugs, or deadline rush due to procrastination, for example (Takahashi, 2005).

In recent behavioral and neuro-economic approaches, neurobiological and psychological factors determining individual differences in intertemporal choice have been explored (Takahashi, 2004; Takahashi, 2005; Takahashi, 2008a-c). Recent studies conducted by mainstream economics researchers have highlighted the relevance of dynamic inconsistency to economic policies. In recent studies conducted by mainstream economics researchers, while in the behavioral economics of addiction, impulsivity/impatience in intertemporal choice has been extensively studied. Consequently, behavioral and neuroeconomic studies of hyperbolic time-discount rates have reported that (i) addicts (e.g., smokers, alcoholics, pathological gamblers, heroin addicts, cocaine addicts, and amphetamine abusers) have large time-discount rates in comparison to non-drug-using controls (Ohmura, Takahashi, Kitamura, 2005), (ii) neuroactive hormones such as cortisol (a stress hormone) and testosterone (a male sex hormone) are associated with temporal discounting (Takahashi, 2004; Takahashi, Ikeda, Fukushima, et al., 2007; Takahashi, Furukawa, Miyakawa, et al., 2007; Takahashi, Sakaguchi, Oki, et al., 2006)), and (iii) neurotransmitters such as serotonin, dopamine, and adrenaline (epinephrine, of which activity in the brain can be non-invasively be assessed by measuring salivary alpha-amylase), and functioning of related neural circuits, are associated with temporal discount rates (Takahashi, Ikeda, Fukushima, et al., 2007). It can be said that how impulsivity in intertemporal choice (indicated by a discount rate) is modulated by neurobiological factors has been relatively intensively studied. However, another important factor in intertemporal choice, inconsistency, has been less extensively scrutinized in a quantitatively rigorous manner.
Fortunately, however, recent neuroeconomic and econophysical studies on intertemporal choice have made it possible to dissociate impulsivity and inconsistency in intertemporal choice, within a unified framework. More tellingly, in the q-exponential discount model (based on non-extensive thermostatistical physics), impulsivity and consistency are distinctly parameterized (Takahashi, Oono, & Radford, 2007). The q-exponential discount model is capable of parameterizing subjects’ inconsistency and impulsivity, separately, in a continuous manner. On the other hand, the generalized quasi-hyperbolic discount model that has been recently proposed in neuroeconomics—note that the conventional quasi-hyperbolic model (i.e., a model) has been proposed in behavioral economics—can parameterize an internal conflict within an agent between impulsive and patient selves at each time-point in intertemporal choice (Takahashi, 2008a). Relationships between these two models and conventional exponential and hyperbolic discount models have recently been investigated (Takahashi, 2008a,b). It is argued that future studies should examine the importance of neuromodulation of the parameters in these two novel discount models.

Furthermore, the importance of nonlinear time-perception following the Weber-Fechner law and Stevens’ power law for a better understanding of intertemporal choice is also introduced (Takahashi, 2005; Takahashi, 2006; Takahashi, Oono, Radford, 2008). For instance, the psychophysics of time-perception may explain a number of anomalies in intertemporal choice—hyperbolicity, subadditivity, and delay/date effects. Finally, some conclusions and implications from the present analysis are presented in relation to future study directions. In discussing future study directions, I have also mentioned the importance of examining the relationship between intertemporal choice and decision under uncertainty (Ohmura, Takahashi, Kitamura, et al., 2006; Takahashi, 2006b, Takahashi, 2007, Takahashi, Ikeda, Hasegawa, 2007), and the usefulness of the novel frameworks for analyzing consistency of governmental economic policy-making.

2. Conclusions and implications

In summary, the importance of studying neurochemical and neuroendocrinological modulations of time-perception and intertemporal choice (e.g. serotonin, dopamine, cortisol, testosterone, adrenaline) by utilizing
the present proposed theoretical frameworks is addressed. Further, the relationship between intertemporal choice and decision under risk is discussed, in relation to evolutionary theorist Sozou’s hypothesis on the hyperbolic decay of the subjective probability of obtaining a delayed reward.

References


VII. Temporal Discounting and Prospective Timing: Is a Value Theory Valid?

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1. Introduction

1.1. A Concurrent-Chains Procedure and Temporal Discounting

Animals' choice between a self-control alternative (larger-later food) and an impulsive alternative (smaller-sooner food) is mainly accounted for by temporal discounting of reinforcement value. Animal studies on temporal discounting have used some variation of a concurrent-chains procedure. This procedure is preferable because it enables us to manipulate reinforcement delay without changing the schedules of reinforcement in a choice period. In the choice period, two identical initial-link schedules are presented, and completion of either schedule leads to the onset of a terminal-link period, at the end of which a primary reinforcer is presented. Therefore, the terminal-link schedule sets a delay to the primary reinforcer. The durations of the terminal-link periods are different, depending on which of the two initial links is completed, and measures of responses in the choice period are regarded as reflecting "preference" between these terminal links. Furthermore, the duration of the terminal-link period is regarded as a determinant of the conditioned reinforcer "value" of the stimulus that accompanies the onset of the terminal link; the duration is inversely related to the value.

There have been several formulations of the relationship between the value of a reinforcer and its delay. Mazur (1987) proposed the hyperbolic function,
$V = A / (1 + k D)$, where $V$ denotes a discounted value of a reinforcer, $A$ denotes amount of a primary reinforcer, $k$ is a parameter for a rate of discounting, and $D$ denotes the duration of delay. Green et al. (1994) proposed the hyperbolic-like function, $V = A / (1 + k D)^s$, where $s$ is a free parameter. Furthermore, Grace (1996) proposed the power function. All these are formulations of how the value of a primary reinforcer is discounted by its delay.

1.2. Prospective Timing or Temporal Discrimination in a Concurrent-Chains Procedure

This view of the effect of reinforcement delay is so common that the discriminative property of the duration of the terminal link has been largely ignored. In fact, although there have been several theoretical attempts to deal with this issue (Gibbon et al., 1988; Killeen & Fetterman, 1988), no experimental procedure that specifically focuses on it has been developed. In the present report, therefore, I propose one variation of the concurrent-chains procedure to shed some light on temporal discrimination of the terminal-link schedule.

The basic procedure is as follows. The initial-link schedules are two fixed-ratio (FR) schedules, which are assigned to two separate operandas (response keys for pigeons). The terminal-link schedules are two different fixed-time (FT) schedules, which provide food independently of animals' responding after a fixed temporal interval has elapsed. For example, choice of the left key starts an FT 1-s schedule, and choice of the right key starts an FT 9-s schedule. After many cycles of the initial and terminal links, a pigeon would come to choose the left key exclusively. Then, an experimenter reverses the assignment of the terminal links to the two keys. After some cycles, the pigeon would develop exclusive choice of the right key, that is, the new "rich" key. Thereafter, the experimenter reverses the terminal-link assignment again; the pigeon would again reverse its choice, and so on. As a result of this reversal-learning procedure, the pigeon would learn to shift its choice immediately after it experiences the FT 9-s schedule. In other words, the choice of the pigeon would come to be under discriminative control of the terminal-link duration that is experienced in an immediately preceding cycle.

This procedure may remind one of the retrospective-timing procedure used
in studies of animal timing (Church & Deluty, 1977; Machado & Keen, 1999). In a typical study of this procedure, a trial begins with presentation of a stimulus of a certain duration, which is followed by the onset of the choice period. An animal’s choice may or may not be reinforced, depending on the duration of the preceding stimulus. For example, a response on one key is reinforced if the duration is one second, and a response on the other key is reinforced if it is nine seconds. Those studies have showed that animal choice can be under discriminative control of the duration of the preceding stimulus. Thus, the controlling variable in the retrospective-timing procedure and the present one might be similar.

However, theoretical treatment of the concurrent-chains procedure has been different from that of the retrospective-timing procedure, at least in terms of the major timing theories such as the scalar expectancy theory (SET; Gibbon, 1977, 1991) and the behavioral theory of timing (BeT; Killeen & Fetterman, 1988). Actually, animal behavior observed in the concurrent-chains procedure has been regarded as a typical example of “prospective” timing. In BeT and in an extension of SET (Gallistel & Gibbon, 2000), essentially the same formulation as delay-discounting of reinforcement, the inverse relation between value of a reinforcer and duration of its delay is used to explain such timing.

The behavior that would be observed in the present reversal-learning procedure with the concurrent-chains schedule does not seem to be easily explained by this formulation, in part because this formulation does not make a specific prediction about trial-by-trial behavior, and also because it is the formulation about “value”, the strengthening or selecting effects of reinforcement on behavior. If this formulation were to explain the reversal performance, the value of a previously “rich” terminal link would have to be overcome by the value of a previously “lean” terminal link immediately after the experience of a new “lean” terminal link. Modeling this idea might be possible, but I doubt that such modeling could be reconciled with other data that show gradual development of preference after reversal of terminal links in concurrent chain variable-interval (VI) FI schedules (Grace, 2002). On the other hand, the temporal discrimination account of the reversal performance in the present procedure is straightforward. It is essentially a trial-based account; an animal shifts its choice when a terminal link in an immediately preceding trial is a longer one, so long as its temporal discrimination is accurate.

The following section describes three experiments with pigeons that use
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the reversal-learning procedure with the concurrent-chains schedule, in order to examine whether pigeons behave adaptively in this procedure, whether their behavior is consistent with "value" theory, and whether their performance is similar to typical performance in the retrospective timing procedure.

2. Experiments

2.1. A Win-Stay-Lose-Shift Procedure

In the first experiments with pigeons, I used the same reversal-learning procedure as the one described above. A fixed cumulative number of responses made to either of two response keys terminated an initial link. Choice of one key was followed by an FT 1-s schedule, and choice of the other by an FT 9-s schedule. When the pigeon chose the key associated with the FT 1-s schedule in five successive trials or more, the assignment of the two FT schedules to the left and right keys was reversed probabilistically. After several sessions of this procedure, the pigeons learned to switch their choice immediately after the reversal. This result suggests that choice behavior in a concurrent-chains procedure can be subjected to discriminative control by the duration of a preceding terminal link, although in past theories the choice behavior has been considered to reflect conditioned reinforcement values of following terminal-link stimuli, a major determinant of which is a terminal-link delay of reinforcement. Our subsequent experiment revealed that when the number of required responses in the initial link was increased, intermediate requirements produced the most accurate reversal learning performance. This may be interpreted as counteracting the results of saliency of preceding choice behavior and the time to complete the next choice behavior that could serve as a retention interval, both of which are functions of the number of required responses.

2.2. A Win-Shift-Lose-Stay Procedure

In the second experiment, I modified the basic reversal-learning procedure used in the first experiment. In each trial, a single peck on either of two keys was reinforced by food presentation following a signaled delay. The duration of the delay was one second on one key and nine seconds on the other. Because this assignment of the delays was reversed after each trial, pigeons' win-shift (choosing the opposite key of a previous choice that resulted in a 1-s delay of
reinforcement) and lose-stay (choosing the same key as a previous choice that resulted in a 9-s delay of reinforcement) choices were reinforced after a 1-s delay. When the pigeons made win-shift choices in five or more successive trials, the assignment of the delays was not reversed probabilistically in one trial, and thereafter the reversal of the assignment restarted, so that the pigeons had opportunities to make lose-stay choices. The pigeons learned this win-shift-lose-stay performance, although some of them showed a strong bias for one of the keys. These patterns of choices cannot be explained by the idea that choices are determined by the values of each key, which in turn are determined by the delays in reinforcement associated with each key. Rather, the pattern indicates that a pigeon’s choice and its consequence in a previous trial served as discriminative stimuli for the next choice.

2.3. Psychophysical Functions of Prospective Timing

The third experiment used the basic reversal-learning procedure to obtain a psychophysical function of prospective timing. Pigeon’s three pecks on either of two identical keys terminated initial links. Terminal links on the keys were 1- and 9-s delay periods, respectively, which were signaled by the same stimuli and followed by food presentation. Every time the pigeon chose the 1-s terminal link in five successive trials or more, assignment of the terminal links to the keys was reversed probabilistically. After this training, the pigeons learned to switch their choice immediately after they experienced the 9-s terminal link; the same results that were found in the first experiment. I then conducted test sessions after every three training sessions. When the reversal occurred in the test sessions, the 9-s terminal link was replaced by a terminal link of another duration that was randomly selected from nine values that were evenly spaced between one second and nine seconds on the logarithmic scale. We obtained a psychophysical function by plotting probabilities of pigeons’ switching their choice against the experienced duration of the terminal links. The bisection point that was determined by 0.5 probability of switching was close to the mean calculated according to a hyperbolic function.
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References


VIII. Impulsive behavior from emotion: Theory and actual research

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Impulsive behavior consists of multiple concepts, defined by a tendency toward acting without forethought, an inability to inhibit inappropriate action, and insensitivity to negative consequences (e.g., Ainslie, 1975; Barratt & Patton, 1983; Eysenck, 1993). Some researchers have suggested that high impulsive tendency individuals (high impulsives) make more commission errors (e.g., Dougherty, Bjork, Marsh, & Moeller, 2000), have a lower physiological arousal level (e.g., Eysenck, 1993), and are more sensitive to boredom (Schalling, Edman, Asberg, and Oreland, 1988), compared with low impulsive behavior tendency individuals (low impulsives).

Our data have supported previous findings; however, a different feature was shown in participants’ physiological responses. Yamaguchi and Suzuki (2007c) indicated that high impulsives have lower blood pressure than low impulsives. Eysenck (1993) has proposed that high impulsives are chronically lower in arousal level. In research examining the relationship between impulsive behaviors and psychophysiological responses, it has been found that impulsive people tend to have physiologically low levels of arousal at rest (Barratt, 1985), although they experience relatively greater increases in arousal in response to stimulation (Carrillo-de-la-Peña & Barratt, 1993).

In terms of the relationship between impulsive behavior and emotion, there is little experimental research available on this topic. Moeller, Barratt, Dougherty, Schmitz, and Swann (2001) have argued that impulsive individuals are insensitive to negative conclusions or punishment.

This study examined what factors influence differences in impulsive behavior, by measuring psychological, behavioral, and physiological responses during a dual task. In addition, this study evoked negative emotions in participants before the dual task via the Paced Auditory Serial Addition Task (Lejuez, Kahler, C. W, & Brown, 2003). This task is a calculation task that was used to induce negative. We hypothesized that high impulsives would show many commission errors, low physiological arousal, and low levels of
negative emotions during these tasks, as compared with low impulsives.

This research used the Impulsive Behavior Inventory as a psychological measure of impulsive behavior tendencies. This inventory was developed by Yamaguchi and Suzuki (2007a), and has five subscales which involve abandonment/panic behavior, physical aggressive behavior, verbal aggressive behavior, indirect aggressive behavior, and impulsive buying behavior. In this study, only the abandonment/panic behavior subscale was used to classify the two groups (high impulsives and low impulsives). Some researchers have suggested that the number of commission errors on the Continuous Performance Test (CPT) is an index of impulsive behavior (e.g., Dougherty et al., 2000). Therefore, this study adopted the CPT as a behavioral measure. This study used a dual task that combined the CPT (as a visual discrimination task) with an audio discrimination task. An autonomic measure (Heart Rate: HR, Systolic Blood Pressure: SBP and Diastolic Blood Pressure: DBP) was used as a physiological index.

The results for commission errors and correct detection in the visual discrimination task were consistent with rates found in previous studies (Figure 1). High impulsives had many of responsive frequencies (as shown in the results for the behavioral measures). Therefore, we suggest that high impulsives may have hyperactive tendencies.

In terms of physiological measures, high impulsives had more quickly decreasing physiological arousal (SBP and DBP) at the beginning of the task than low individuals, and this phenomenon occurred regardless of task type (Figure 2). This result supported our previous findings (Yamaguchi & Suzuki, 2007c), and those of Mathias and Stanford (2003). The hyperactive tendencies of high impulsives may relate to their low physiological arousal levels.
Moreover, high impulsive individuals did not feel a mental demand in the task, compared with low individuals. It was suggested that high impulsives were not sensitive to boredom (mental demand), though boredom was not directly examined in this research.

References


IX. The impulsive decision style and cognitive-affective decision processes

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1. Measuring impulsive decision-making style

This study used self-report measures to explore the effect of the impulsive decision-making style on the decision process, and on emotional responses.

Individuals cope in varying ways with the conflict and corresponding emotions resulting from the decision-making process. Decision-making style refers to the coping pattern usually adopted by an individual in a decision conflict. Janis and Mann (1977) proposed five coping patterns, among which vigilance is said to result in thorough information search, unbiased assimilation of information, and other characteristics of high quality decision-making (p. 52). In contrast, hypervigilance results in the opposite determinants, and consequently leads to impulsive or ill-considered decision-making. The developmental psychologist Kagan (1965) proposed that a cognitive style, which is a tendency to process information in a certain manner, could explain how people behave in different situations. Kagan proposed the impulsive vs. reflective cognitive style, that was conceptualized in terms of individuals’
response times and errors when placed in a decision-making situation. For example, reflective children, who are associated with thinking before acting, respond slowly but without error. On the other hand, impulsive children, who are associated with fast reaction times, respond quickly but with many errors, as measured by the Matching Familiar Figure Test (MFFT).

Several scales assessing decision-making and cognitive styles have been developed. For example, Radford and Nakane (1991) developed a 24-item instrument to explore decision-making styles, based on the work of Janis and Mann (1976). Japanese social psychologists Takigiku and Sakamoto (1991) constructed a questionnaire to measure the impulsive-reflective cognitive style (10 items), based on the Yatabe-Guilford personality scale. They demonstrated the construct validity of their instrument by comparing it to the MFFT and other scales.

In our studies, we used the abovementioned scales as measures of decision-making style. We conceptualized a unified meaning for impulsive decision-making, which includes an intuitive decision-making style in low and middle stressful situations (e.g., choosing a university to go to) and the state of hypervigilance in high stressful situations (e.g., taking a genetic test). In our studies, the concept of impulsivity is opposite to an analytic, reflective, deliberative decision-making style, and to the state of vigilance. We will discuss research on the relationship between an impulsive decision-making style and cognitive-emotional process in several important decision-making situations.

2. Impulsive decision style and decision stress

To explore the relationship between impulsive decision style and decision stress, we used the decision-making style scale developed by Radford and Nakane (1991) in an authentic stressful decision-making situation (choosing a job) as well as in a fictional decision-making situation (deciding whether or not to take a genetic test).

Kusumi (1995) conducted a survey study that addressed individuals’ decision-making style, decision stress (Radford & Nakane, 1991), and occupational readiness (Shimomura, 1996). Participants were 106 senior undergraduate students who were asked questions concerning the real-life career decision-making that they were about to make in their lives. Correlational analyses suggested that the impulsive decision style was related to a high
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Similarly, Kusumi et al. (2006) conducted a questionnaire survey of 120 university students, to explore their decision-making processes when deciding whether or not to take a genetic test. Individual differences in decision-making styles (Radford & Nakane, 1991), the determinant factors of support needs, and their perceptions of inheritances were also assessed. In three vignettes (diagnosis, marriage, and birth concerning genetic disease), participants rated their willingness to take a genetic test, the difficulties with the decision-making process, and their support needs.

The results showed that participants had some basic knowledge of heredity; however, they possessed little knowledge of genetic diagnosis. They merely wanted to learn any negative test results. Figure 1 shows a causal model of support needs for genetic testing: (a) An impulsive decision style causes fear of genetic tests and poses difficulties in decision-making, (b) fear of genetic tests suppresses the willingness to take the test due to difficulties in decision-making, (c) life planning promotes a willingness to take the genetic test and decreases the difficulties of making the decision, and (d) it also increases the...
need for psychological support for one's worries and the decision-making process.

The results revealed significant relationships between impulsive decision style, decision stress, process and support needs in both real career decision-making and in a decision about fictional genetic testing.

3. Impulsive decision style and regret

To explore the effect of an impulsive decision-making style on decision process and on regret in naturalistic decision situations, we used analytic-intuitive decision style items, which were based on the cognitive reflective-impulsive scale developed by Takigiku and Sakamoto (1991).

Ueichi and Kusumi (2004) investigated changes in feelings of regret over time, in relation to an intuitive-analytic decision-making style and coping methods for dealing with the regret. Seventy undergraduate students completed a questionnaire on decision-making styles, critical thinking, feelings of regret and coping methods across five different situations: Entrance examinations, declarations of love, skiing, career changes, and investments.

Results showed that in situations which normally occur only once (i.e., entrance examinations), analytic decision-makers tended to cope with their regret by improving their behavior, more than did intuitive decision-makers. Critical thinkers tended to adopt an analytic style more often than an intuitive style.

In another study, Ueichi et al. (2007) examined the effects of the intuitive-analytic decision-making style on students' choice of which university to attend, on their emotional reactions (regret, satisfaction, and disappointment), and on their coping with regret (rationalization, improvement with greater effort, and changing one's own actions). We surveyed 352 third-year high school students both while they were in school and after graduation, using written questionnaires.

Results showed that analytical type affected decision-making strategy, a relationship mediated by gathering of information, whereas intuitive type affected decision-making strategy directly. Complete strategy affected the selection of first-choice universities, mediated by utility for first choice, whereas constraint satisfaction affected the selection of second-choice universities, mediated by utility for second choice. The analytic style decreased
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negative emotions (regret and disappointment), and increased later ability to cope with regret.

These results revealed that intuitive or impulsive decision-making styles increase regret as well as decrease the chances of coping with this emotion. Although it is important to encourage people to deliberate carefully when deciding about their futures, the intuitive and impulsive decision-making styles may be adaptive when people are deciding about unimportant problems under time pressure.

4. Conclusion

The fact that responses to subjective impulsive decision-making style scales are related to individuals’ decision-stress, non-deliberate decision processes, decision support needs, regret and failure of coping with regret in both real and vignette important decision situations suggests that the self-report measure is a valid tool for studying impulsive decision-making.

The advantage of using self-report measures of impulsivity is that it allows for the application of various decision situations and the investigation of the relationships among multiple variables (such as individual differences and situational factors). However, it is also important to check the validity of subjective impulsivity scales via other means, such as experimental and real life situations, social survey studies, and neurophysiological studies.

References


X. Assessment of impulsivity in children with developmental disabilities

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1. Introduction

Young children might commonly be active, energetic, and exuberant, and might tend to flit from one activity to another as they explore their environment and its novelties. But when children persistently display levels of activity that are far in excess of their age group peers, and when their impulse control and self-regulation lag far behind expectations for their developmental level, they are highly likely to experience a number of problems across several domains of development and adjustment (Barkley, 1997). These children are often considered to have Attention-Deficit Hyperactivity Disorder (ADHD).

ADHD is a common behavioral syndrome, estimated to occur in 3-7% of school-aged children worldwide. Symptoms include low levels of attention and concentration, and high levels of activity, distractibility, impulsivity, and an inability to inhibit actions. One of the most influential theoretical models of ADHD posits that deficits in behavioral inhibition are at the core of ADHD symptoms (Barkley, 1997; Liotti et al., 2007). In support of that model, impairment has been found in children with ADHD on laboratory tasks that tap into the inhibitory control processes thought to underlie ADHD (impulsiveness and inattention), such as the Continuous Performance Test (or
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The CPT is an attention task in which a series of stimuli are presented, and is divided into CPT-X, CPT-AX, and CPT-Double by target demand (Corkum and Siegel, 1993). Above all, CPT-AX is the paradigm where subjects are asked to respond to a target within a cue-target sequence (such as A-X). As expectations released by the warning stimulus might affect motor behavior, CPT-AX is an optimal paradigm for investigating anticipated motor control and impulsive responding.

As well as behavioral performance (Okazaki et al., 2001), electrophysiological data have complemented and extended the neurocognitive findings on motor control (Okazaki et al., 2004a, 2004b). The deficits of motor inhibition seen in children with ADHD might be concerned with functional states of their prefrontal cortices (Sergeant et al., 2002; Okazaki & Ozaki, 2006).

In this study, we focused our interest on the neurocognitive process of impulsivity / response inhibition in children with ADHD, using the CPT-AX with different intervals between stimulus signals.

2. Methods

Children with ADHD (N=11, all boys, mean age 11: 4 ± 0: 5) and normal controls (N=8, 6 boys and 2 girls, mean age 11: 3 ± 0: 4) participated in this study.

The time sequence of stimulus presentation in the CPT-AX is shown in Figure 1. Subjects were asked to press a button when “9” appeared immediately after “1”. To maintain temporal uncertainty in the stimulus series, we implemented three different inter-stimulus intervals (ISIs) between the warning stimulus and the subsequent target and the non-target (no-go). The probability of the target and the no-go was five percent under each ISI condition. A series of four hundred digits was presented for each block, and two blocks were tested.

EEGs were recorded from 17 locations on the scalp (10-20 system without Fp1 and Fp2) against the linked earlobes as a common reference.
3. Results and Discussion

3.1. Performance on the CPT-AX

Children with ADHD showed a lower hit rate than that of controls. ADHD children also had more false alarms than did the controls.

ERP during CPT-AX

In the grand mean ERP map series from 250 to 450 ms after stimulus onset (Figure 2), there were two different successive segments under each condition, i.e., P2/N2 with posterior-positivity and anterior-negativity and P3. These components are observed in both groups; however, intensities of P2/N2 and P3 in the ADHD children were lower than those in the control children, especially in P2/N2 under the no-go condition. These results are suggestive of under-activation during a relatively early stage of visual information processing in ADHD. Such under-activation of early processes might ultimately disturb acquisition of an appropriate motor behavior. These mal-acquisitions might be related to insufficient interaction between anterior and posterior cerebral structures.

3.2. Case study of assessment of impulsivity in a child with ADHD

As each child with ADHD has a unique developmental history, a longitudinal study of how an individual with ADHD acquired his or her ability to control
motor actions would supplement and extend existing findings. Therefore, we considered that a follow-up study of the same individual would not only complement and extend the findings obtained from cross-sectional studies, but might also reveal a developmental course for an individual with ADHD (Okazaki et al., 2004). As it turns out, longitudinal changes in ERP do correspond with intra-individual changes in behavioral performance. Moreover, an individual characteristic of impulsivity was reflected in the electrophysiological data. In one case (age 10:3, male), performance on the CPT-AX was characterized by a large number of false alarms to no-go stimuli. An ERP waveform elicited by incorrect trials during the no-go condition showed diminished positivity during 400 to 600 ms (Fig. 3). These results suggest that under-activation of orientation and evaluation of stimulus relevance affected later control of the motor response.

4. Conclusion

Because of the diversity of individual developmental courses, both cross-sectional data and longitudinal follow-up data will be needed to determine the developmental features of response control in children with ADHD. The findings obtained through this strategy might offer important information to improve intervention and therapies provided to children with ADHD.
Figure 3. ERP waveforms elicited by each stimulus and condition in child with ADHD (10:3, male).

References


