Title
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Inverted-U and Inverted-J Effects in Self-Referenced Decisions

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Abstract

Rating one's own personality traits is a common self-referential information processing task. The current paper examined the mechanism underlying this sort of trait-rating task by using a PC cursor tracing technique (Shiina, 2011a, b). The target phenomenon of interest was the inverted-U effect observed in trait ratings. The PC cursor tracing technique analyzed response times, tangential velocities, and rapid cursor movements (strokes). Results supported Klein's notion (Klein et al., 2002) that self-referenced episodic and semantic memories are used independently when making these trait decisions.

Keywords: Rating decision; inverted-U effect; decisional fluctuation.

Trait Ratings and Inverted-U Effects

Personality trait rating tasks are the typical research paradigm in the field of self-referential judgments and decisions, which are an important topic for social and neurocognitive scientists (Lieberman, 2007) as well as psychometricians. When making trait ratings with Likert-type scales, it was found that trait rating needs more time in the moderate than in the extremes of the scale. Response characteristics of this type can emerge in other dependent variables, and Mignault, Marley, & Chaudhuri (2008) called them, the inverted-U response time, error, and uncertainty effects, respectively. The inverted-U effect has been observed in two major domains that use scale-like response formats: personality trait ratings (Judd & Kulik, 1980: Kuiper, 1981; Mueller, Thompson, & Dugan, 1986; Akrami, Hedlund, & Ekehammar, 2007) and absolute identification judgments in psychophysics (Stewart, Brown, & Chater, 2005: Brown, Marley, Donkin, & Heathcote, 2008).

Two views on of self-referential ratings If you are asked to rate whether "You talk a lot" on a Likert-type rating scale, what is the mental computation needed to do this task? A social cognitive scientist might argue that if you are talkative in all aspects of your life, then you will consider yourself as talkative based on your self-reflections and the exogenous evaluations made by your family and friends. In this case, talkativeness is a stable personality trait and the proposition "I talk a lot" is directly stored in your semantic memory, and thus the rating judgment will be quick and reliable.

In contrast, if you do not have either of the following propositions—"I talk a lot" or "I do not talk a lot"—in your memory, you should compute the truth of the proposition at the moment. You will try to retrieve episodes concerning your talkativeness from your memory and may find that, for instance, you are eloquent in public but very quiet at home. This creates an internal conflict, which leads to settling on a midpoint rating. The rating judgment will be slow and unstable. The combination of the above two different modes of processes, that is, the quick retrieval and slow deliberation processes, creates an inverted-U effect.

A psychometrician will embrace a completely different view (Thurstone, 1959; Tourangeau, Rips, & Rasinski, 2000). She or he first assumes a psychological continuum of "talkativeness" and further assumes that people have a specific position on the continuum. The self-rating is considered as a self-observation on the continuum. Although there do exist many sophisticated scaling models, it is reasonable to say that the most popular and oft-used method is still Likert-type scaling procedure within the framework of the classical test theory. For the psychometrician the rating scale is a black-box and little attention will be paid to the internal information processing. Psychometric view will predict that the rating times are flat across rating categories. A more elaborated view may predict, however, that the highest and lowest categories can have less chances of being confused because they have only one neighbor category.

In sum, both views can predict the inverted-U patterns via completely different assumptions and thus a method that can produce another type of information is needed.

Trajectory tracing The current study attempted to understand the inverted-U effects by employing the technique of PC cursor trajectory tracing (Figure1), in view of the recent upsurge in cursor trajectory analysis that can capture cognitive components of decisions (for reviews, see Song & Nakayama, 2009; Freeman, Dale, & Farmer, 2011). By analyzing cursor trajectories in PC based ratings, it was expected that the method could provide direct evidence showing that the inverted-U effect is a joint effect of extreme trait ratings that are memory-based and made without conflict, and moderate trait ratings that are modulated by internal conflict resolution. A total of 16 rating tasks (Table 1), 10 of which pertained to personality traits and thus to self-referenced decisions, were analyzed and contrasted.

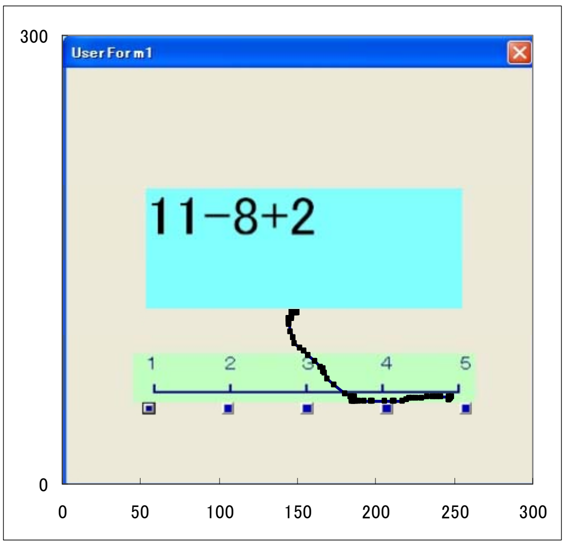


Figure 1: The form used in Task 13 in Table 1, along with an example of trajectory, which traveled from "Start" button to Category 5. The start button was erased after the initial click.

The Data

Overview The rating data are a compilation of the author's past studies over a 5-year period (Shiina, 2008, 2011a, 2011b, 2012). The data were gathered from 568 participants and the same experimental procedure and PCs were used. Tasks 0-10 were administered to the pool of 140 subjects. The other tasks were administered to different pools of participants. This was done because as many as 16 tasks (Table 1) were compared at the same time in the current study to detect the inverted-U, inverted-J, and other patterns.

Procedure The form shown in Figure 1 was used to record trajectories, final rating judgments, and response times. There were 5 ordered categories with either a set of numerical labels from 1 to 5 as shown in Figure 1 or with a set of verbal labels "no", "don't know", and "yes" in the position of categories 1, 3, and 5, respectively. There were no labels at the positions of 2 and 4. The rating experiment was subject-paced. As soon as the subject clicked the "Start" button superimposed at the center of the form, the button was erased and a problem appeared in the display box in the center of the form. Participants were asked to click a "correct" or "most suitable" category button as quickly as possible. The cursor trajectory and the time between the initial and last clicks were registered. Then "Start" button reappeared to proceed to the next trial by calling up the next problem. An experimental session included several of the tasks in Table 1 and thus the number of trials for each subject was around 100. The experimental program was written in VBA for Microsoft Excel and the experiment was run on Excel.

Tasks Sixteen tasks were used across different cognitive and self-referenced domains (Table 1). The first task (Task 0) was a Benchmark task in which one of the numbers from 1 to 5 was randomly presented and subjects were asked to click the corresponding button on the form. A previous study (Shiina, 2008) showed that the trajectories in this task show typical goal-directed (simple reaching) movements and thus this task served as a baseline that involved a minimum of cognitive workload. Tasks 1-12 were internally-guided tasks with no correct answers: Tasks 1-10 were standard psychological scales that were the major target of the present study and Tasks 11-12 were cognitive tasks that evoke deep cognitive processing but were not directly related to the self.

Tasks 13-15 were externally-guided tasks with correct answers. In Task 13, the stimuli were simple math expressions that included addition and subtraction of three digits (e.g., 3-2+1). The participants' clicked the correct number as quickly as possible. Task 14 was a division task in which participants divided one prime number by another number (e.g., 17/13) and rounded the answer off to the nearest integer to click the category button. Task 15 consisted of difficult geography quizzes that demand deliberation. All the tasks were presented in Japanese. The psychological scales were Japanese versions.

Participants The number of participants for each task is shown in Table 1. All participants were Waseda University undergraduates.

Table 1: Summary of 16 Tasks

	Items	N
0) † Benchmark	25	140
1) Self esteem (Rosenberg)	10	140
2) Maximization (Schwartz)	8	140
3) Regret (Schwartz)	8	140
4) Big 5 Extraversion	5	140
5) Big 5 Neuroticism	5	140
6) Big 5 Conscientiousness	5	140
7) Big 5 Agreeableness	5	140
8) Big 5 Openness to Experience	5	140
9) Indeterminacy	15	140
10) Social desirability (Marlowe-Crowne)	10	140
11) Life style (e.g., We can be happy without money)	5	185
12) Opinion (e.g., Japan has rather a bright future)	5	185
13) †Addition and subtraction (e.g., 3-2+1, 1+3-2.)	30	70
14) † Division (e.g., 17/13.)	10	173
15)Geography (France is larger than Japan in land area)	5	185

Note. † "1-2-3-4-5" Category label was used. Otherwise "No-Don't know-Yes" label was used.

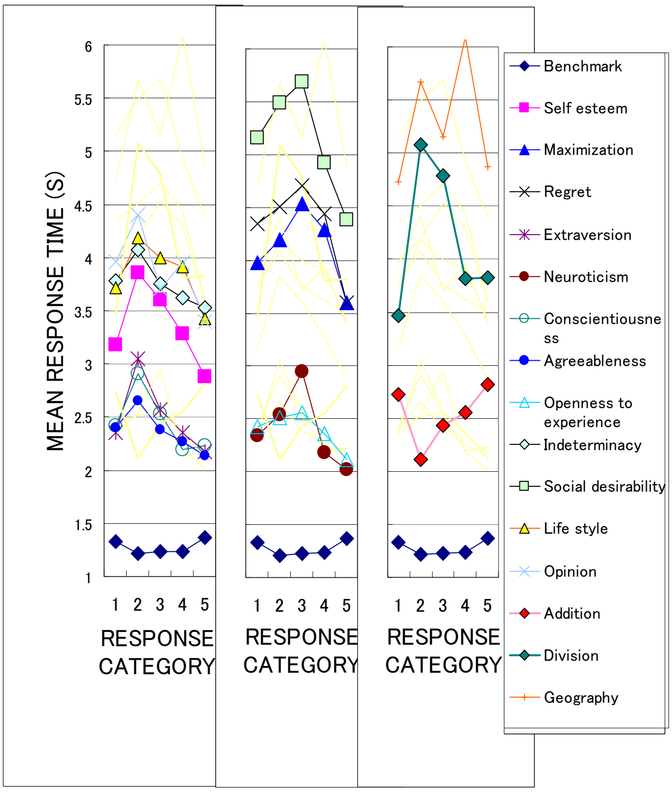
Response Time Analysis: Inverted-J RT Effect

Figure 2 displays the mean response times as a function of the final category clicked for the 16 tasks. We can find that 13 curves have and 3 curves do not have an inverted-U shape. Interestingly, many of the inverted-U patterns were from internally-guided (no correct answer) tasks (Tasks 1–12). The 3 curves that were not inverted-U shaped were from Benchmark, Addition and subtraction, and Geography tasks.

Emergence of inverted-J patterns It was further observed that in the 12 curves out of the 13 inverted-U curves, YES responses (category 5 responses) were faster than NO responses (category 1 responses). These response patterns produced *inverted-J* rather than inverted-U shapes and the exception was Task 14 (Division), which was an externally-guided task. In Figure 2, panels (a) and (b) show inverted-J patterns with different maxima. All the inverted-J patterns were from internally-guided (no correct answer) tasks (Tasks 1-12) including all the self-descriptive psychological scales (Tasks 1-10).

The emergence of the inverted-J pattern in self-referenced ratings is not new but has never been claimed explicitly. We can see clear inverted-J-shaped patterns in Mueller et al (1986, Figure 1, for trait adjectives) and Akrami et al (2007, Figure 1, for Big 5 traits) as well, although many of the previous studies do not include graphs that show this relationship between rating categories and a dependent variable. The reason why the previous studies did not highlight the inverted-J shapes would be that they dealt with relatively few traits and descriptions and could not discover the statistical regularity across traits.

Inverted-J patterns will be the target of the present study, although more data is needed to conclude the generality of inverted-J patterns in self-referenced or internally-guided ratings.



(a) (b) (c)

Figure 2: Mean RTs as a function of the final category chosen. (a) Inverted-J with maximum at Category 2, (b) Inverted-J with maximum at Category 3, and (c) No inverted-J.

A possible explanation of inverted-J patterns Klein, Cosmides, Tooby, & Chance (2002) argue that judgments about the self use two independent memories: an episodic store, which represents specific events and behaviors involving the self, and a semantic store, which includes summaries of the personality traits abstracted from a set of particular events. Klein et al. further argue that the two memory systems are independently represented and used. Within this framework, the inverted-J effect can be schematically explained as follows: "Yes" responses are the fastest because direct retrieval from semantic memory is at work. "Don't know" responses are the slowest because, to arrive at this category, participants should first compute the degree of consistency to the trait by using episodic stores and then fail to attain high or low consistency. Finally, "No" responses are intermediate because both direct stores and computation using episodic stores are at work.

An immediate criticism to this interpretation is that if the affirmative proposition "I have Trait X" can be directly stored in semantic memory, there is no logical reason to exclude the possibility that a fuzzy proposition, "I have Trait X moderately", can be stored in the semantic memory as well. The trajectory analysis now comes in.

Trajectory-Analysis 1: Averaged Velocity Shape

We define a trajectory as a time-indexed 2-dimensional vector: $(x(t), y(t))$, $0 < t < RT$). We first divide the RT by 256 to define a step size in time domain, and then estimated the location of (x_i, y_i), $i = 0, 255$ by linear interpolation in order to "standardize" the trajectories. Tangential velocity of a trajectory at time *i* is defined as:

$$TV_i = \frac{\sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2}}{RT/256} = \frac{\textit{Traveled Distance}}{\textit{time step}}$$

Tangential velocity is the speed of the trajectory, which reflects task characteristics. See Shiina (2008, 2011a, b) for more details.

Average tangential velocity The average tangential velocity curves as a function of time and a final rating category clicked were computed (Figure 3. Due to space limitation, not all relevant figures could be presented). For example, Figure 3a depicts the 5 average tangential velocity curves in Benchmark Task corresponding to the rating categories finally clicked. The numbers in the parentheses are mean RTs. In this task, a cursor movement should be a type of simple reaching movement with an initial ballistic phase and a second corrective control phase. Ballistic movements are quick and bell-shaped, and imply that there is dissociation between motor and cognitive components, because ballistic movements are under feed-forward control and thus their initial velocity and direction should be determined *before* the initiation of the movement (Elliott, Helsen, & Chua, 2001). In contrast, non-ballistic movements reflect the examinee's decisional conflict and vacillation. Therefore, a ballistic movement can be used as a marker to indicate no-hesitation. Because the curves in Figure 3a show an initial large bell-shaped ballistic movement (a peak on the left) followed by small corrective movements (small vibrations on the right), we can define that a bell-shaped curve whose top speed is over 200 dot/s is a ballistic movement. With reference to this rule, we can judge that the tangential velocities of the trajectories aiming at categories 1 and 5 tended to be ballistic and the curves toward the middle categories were non-ballistic.

More specifically, we can judge that there is no simple reaching movement in Division and Indeterminacy Tasks, and the trajectories aiming at categories 1 and 5 in Extraversion Task (Figure 3b) are ballistic. Further, we can observe in Figures 3c and 3d that all the curves moved slowly in the initial period, which is apparently related to reading or calculation.

This analysis might appear somewhat tautological because there is no wonder if a quickly moving cursor reaches its destination faster. This criticism would be valid if the cursor movements were always optimal and economical, but trajectories with unwasted motion were very rare.

Because a ballistic movement is quick and reflects no-hesitation, this analysis gives a crude explanation of the inverted-U RT effect but cannot predict the inverted-J effect. A finer analysis will be presented in the next section.

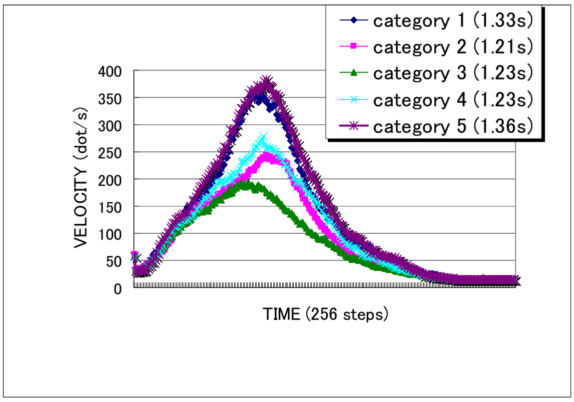


Figure 3a: Average tangential velocities in Benchmark Task.

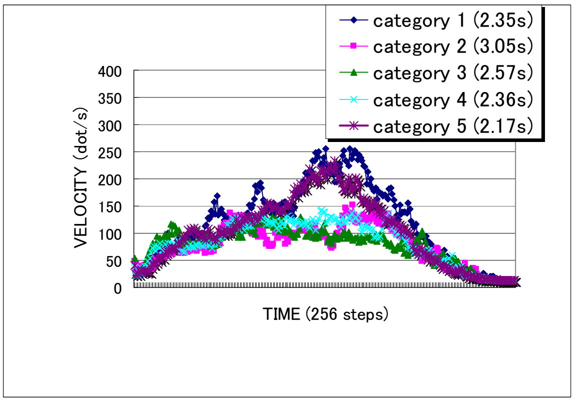


Figure 3b: Average tangential velocities in Big 5 Extraversion Task.

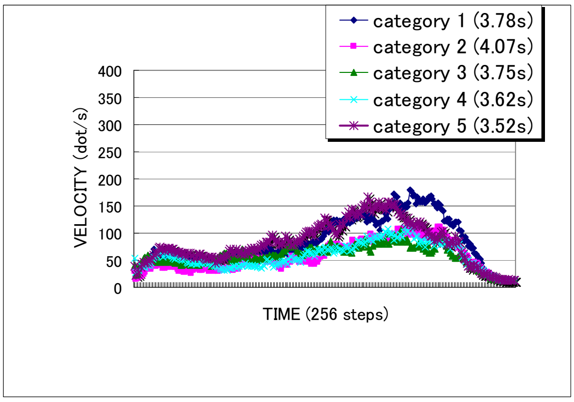


Figure 3c: Average tangential velocities in Indeterminacy Task.

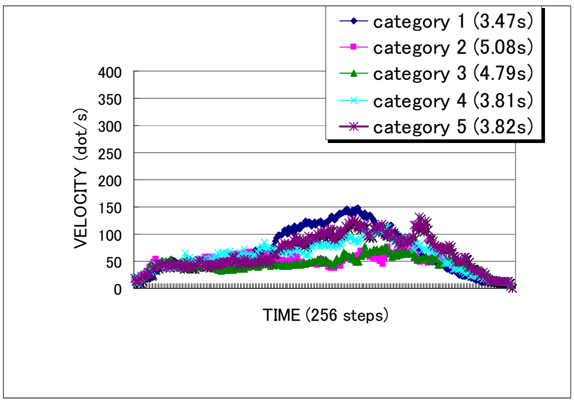


Figure 3d: Average tangential velocities in Division Task.

Trajectory-Analysis 2: Velocity Variability

Having noticed that an analysis of average curves alone is insufficient to explain the inverted-J effect, we conducted another analysis focusing on variability of velocities. Let $\bar{X}_i$ =average of tangential velocities at time *i*

s_i = standard deviation of tangential velocities at time *i*.

$CV_i = s_i / \bar{X}_i$ =*variation of an average velocity curve at time i* (Pearson's Coefficient of Variation).

Because larger quantities tend to have larger variations, the index measures trajectory-variability taking account of magnitudes of averages. If CV_i 's are averaged over all time points, we obtain 80 (16 Tasks X 5 Categories) estimates of trajectory variabilities corresponding to all the points in Figure 2. The trajectory variability indices reflect internal indeterminacy of participants. Using the CV index, a quadratic model:

RT = 0.065 × (Number of letters of a question) +0.285× (category number) - 0.072 × (category number) ^2 + 1.359×CV -0.434

could produce the 12 inverted-J curves for internally guided tasks (Figure 2) very well (R^2 = .94, F (4, 55) =201.79, p<.0001, Figure 4). In this formula, the number of letters comprising a question determines the overall level of response times, the quadratic part generates inverted-U shapes, and the CV part transforms U to J meaning that the CV's for Category 5 were small and for the middle categories were large.

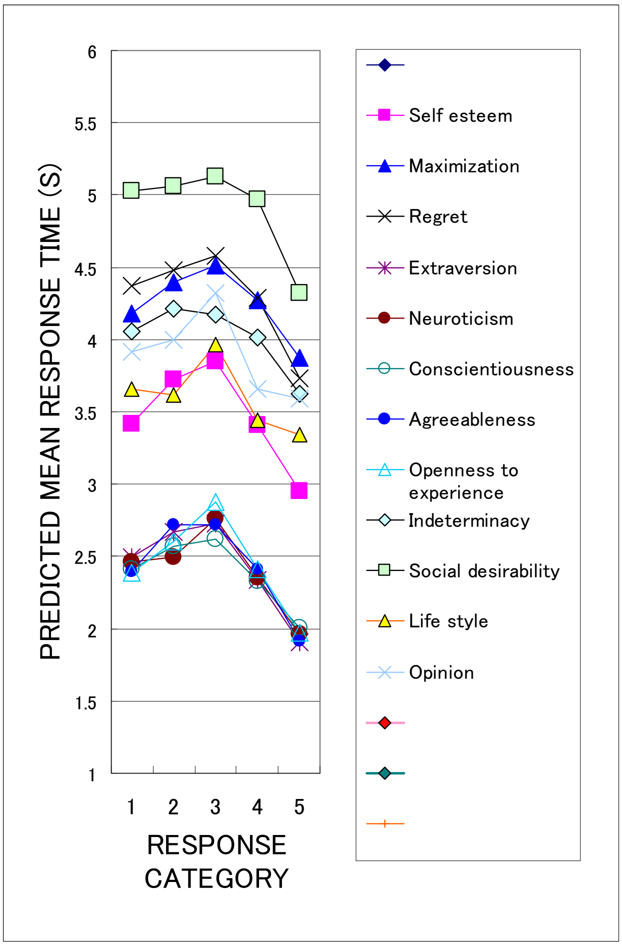
A natural interpretation of this result is that the trajectories toward the middle categories were shuddering and thus increased the response times. If the assumption that trajectory-variability (CV) reflects internal conflict is valid, we can infer a causal chain: internal fluctuation -> trajectory perturbation ->longer response times -> inverted-U (-J) effect.

The result and interpretation seem to be reasonable, but we do not know why CV's for the middle categories were large and for Category 5 were small. The next analysis addresses this question.

Trajectory-Analysis 3: Stroke Analysis

Shiina (2011b) reported that a cursor trajectory often includes pulse-like movements (Figure 5) called strokes and over 50% of velocity curves were single peaked in the Benchmark Task whereas the rate was much lower in other tasks. Therefore, another interpretation for average velocities in Figure 3 is that they are a fusion of pulses (strokes) reflecting pulse frequencies. Similarly, another interpretation of CV values is that they are measuring instability (time heterogeneity) of discrete events at time *i*.

Because ballistic single-stroke velocity curves imply no internal hesitation whereas multiple stroke velocities imply internal conflict, the proportion of single peaked trajectories was calculated for each category in each task (Figure 6, Shiina, 2011b). The figure looks disordered but a clear J emerged by averaging the curves. The results strongly supports the view that less internal conflict



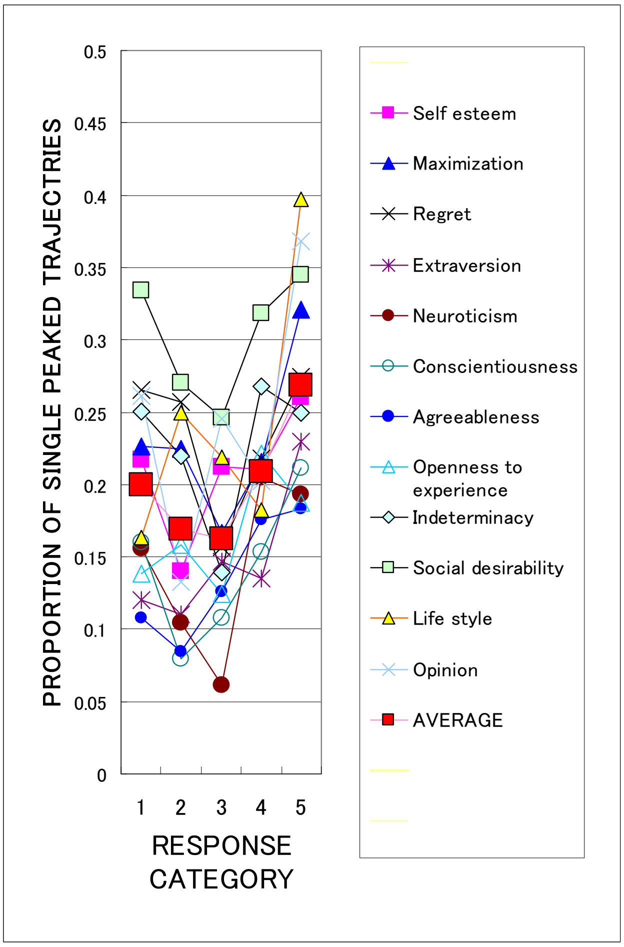
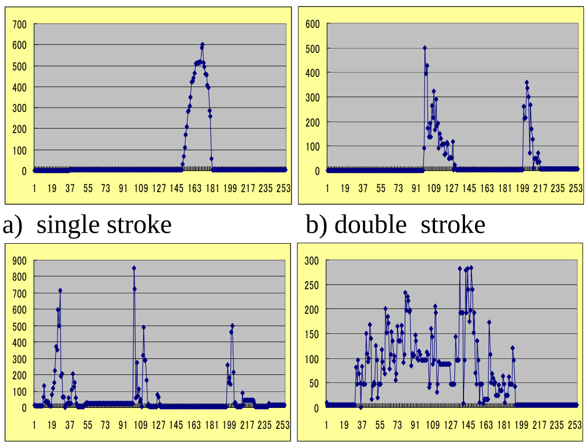


Figure 4: A quadratic model that mimics inverted-J curves in Figure 2.

Figure 6: Proportion of single-peaked trajectories as a function of rating category. Average curve (Large red square) shows a clear J-pattern.



a) single stroke b) double stroke

c) triple stroke d) drift

Figure 5: Examples of raw velocity curves found in Division Task (Shiina 2011b). The pulses are called strokes. The abscissa is time and the ordinate is tangential velocity.

increases single peaked ballistic movements, and ballistic movements induce shorter RTs, which yield the inverted-J curves.

Summary and Discussion

1) The inverted-J RT effect occurred as a function of tasks, especially when tasks were internally guided.
2) The tangential velocity analysis suggested that ballistic movements are a plausible source of inverted-J effects.
3) The trajectory-variability analysis showed that the trajectory variability index (CV) could produce a reasonable quadratic regression model (Figure 4) that mimics the inverted-J patterns in Figure 2.
4) The stroke analysis revealed that single peaked trajectories, which can be interpreted as a marker of non-hesitation, are a source of quick responses and the inverted-J effect.
5) It is plausible that participants' conflict causes internal fluctuations, which then manifests multiple-strokes and trajectory vibrations that lead to the inverted-U effect.
6) The ultimate reason for the inverted-J effect is unknown. A possible explanation is presented in the following section.

It has been suggested that extreme ratings are memory dependent whereas the middle ratings are process-dependent and these qualitatively different mechanisms create the inverted-J effect. The emergence of the inverted-J effect is by no means surprising for memory researchers, whereas the effect is very difficult to explain for psychometricians. Therefore, the implication of the present results for psychometrics is that numbers arising from rating decisions are qualitatively different.

What is the inverted-J effect? Why should the response patterns be inverted-J shaped in self-description judgments? A simple explanation would be as follows: when a stimulus statement is either very consistent or very inconsistent with the self-description in memory, rating decisions becomes easier and quicker than when the statement is neither consistent nor inconsistent. This interpretation is rather faulty, however, because if the stimulus statement is "I talk a lot" and you have the proposition "I am average in talkativeness" directly in memory, you should be able to check a moderate rating category equally quickly. To validate the consistency-based interpretation, therefore, we should either prove that very few intermediate propositions are stored in memory or present direct evidence that moderate ratings tend to be interrupted by decisional conflict. The contribution of the present study is that it provided the behavioral evidence that trajectories toward middle categories are fluctuating and those toward extreme categories are stable, producing the inverted-U effect.

Strictly speaking, the above explanation is valid only for the inverted-U effect but not for the inverted-J effect, because, if the probability that "I do not have Trait X" is stored in memory is approximately the same as the probability that "I have Trait X" is stored in memory, the above explanation cannot account for the inverted-J effect. Therefore, a supplementary assumption that there are more affirmative propositions than negative propositions in memory might be needed. For example, if you are a teacher, then you are not a farmer, a fisher, or a carpenter, and so on. Negative propositions would be too numerous to be stored in memory and you need not (and should not) store such an endless list in your memory. Of course, it is undeniable that not a few negative propositions are stored in semantic memory: the point is that the number of propositions that correctly describe you should be far fewer than the number of propositions that wrongly describe you. The inverted-J effect may be a "Yes-effect" arising from information parsimony and asymmetry in memory. The "Yes-effects" would have a strong connection to the acquiescence effect (Krosnick, 1999) and SNARC effect (Dehaene, 2011), although more research is needed to fully address this matter.

References

Akrami, N., Hedlund, L., & Ekehammar, B. (2007). Personality scale response latencies as self-schema indicators: The inverted-U effect revisited. *Personality and Individual Differences*, **43**, 611-618.

Brown, S. D., Marley, A. A. J., Donkin, C., & Heathcote, A. (2008). An integrated model of choices and response times in absolute identification. *Psychological Review*, **115**, 396-425.

Dehaene, S. (2011). *The number sense (2nd Edition)*. New York: Oxford University Press.

Elliott, D., Helsen, W. F., & Chua, R. (2001). A century later: Woodworth's (1899) two-component model of goal-directed aiming. *Psychological Bulletin*, **127**, 342-357.

Freeman, J. B., Dale, R., & Farmer, T. A. (2011). Hand in motion reveals mind in motion. *Frontiers in Psychology*, **2**, 59.

Judd, C.M., & Kulik, J.A. (1980). Schematic effects of social attitudes on information processing and recall. *Journal of Personality and Social Psychology*, **38**, 569-578.

Klein, S. B., Cosmides, L., Tooby, J., & Chance, S. (2002). Decisions and the evolution of memory: Multiple systems, multiple functions. *Psychological Review*, **109**, 306-329.

Krosnick, J.A. (1999). Survey research. *Annual Review of Psychology*, 50,537-567.

Kuiper, N. A. (1981). Convergent evidence for the self as a prototype: The "inverted-U RT effect" for self and other judgments. *Personality and Social Psychology Bulletin*, **7**, 438-443.

Lieberman, M.D. (2007). Social cognitive neuroscience: A review of core processes. *Annual Review of Psychology*, 58, 259–89.

Mignault, A., Marley, A. A. J., and Chaudhuri, A. (2008). Inverted-U effects generalize to the judgment of subjective properties of faces. *Perception & Psychophysics*, **70**, 1274-1288.

Mueller, J. H., Thompson, W. B., & Dugan, K. (1986). Trait distinctiveness and accessibility in the self-schema. *Personality and Social Psychology Bulletin*, **12**, 81-89.

Shiina, K. (2008). Vacillation and hesitation in category rating: Evidence from PC cursor trajectories. *Proceedings of the 30th Annual Conference of the Cognitive Science Society* (pp.1894-1899)**.**

Shiina, K. (2011a). Trajectory-variability and inverted-U effects in rating decisions. European Perspectives on Cognitive Science: Proceedings of the European Conference on Cognitive Science.

Shiina, K. (2011b). Tracing the process of rating decisions through cursor movements. *Proceedings of the 33rd Annual Conference of the Cognitive Science Society*

Shiina, K. (2012). A cursor-tracing paradigm for rating decisions: Another window on mind? Paper read at SJDM Meeting.

Song, J. H., & Nakayama, K. (2009). Hidden cognitive states revealed in choice reaching tasks. *Trends in Cognitive Sciences*, **13**, 360-366.

Stewart, N., Brown, G. D. A., & Chater, N. (2005). Absolute identification by relative judgment. *Psychological Review*, **112**, 881-911.

Thurstone, L.L. (1959). *The measurement of values.* University of Chicago Press.

Tourangeau, R., Rips, L. J., & Rasinski, K. (2000). *The psychology of survey response.* Cambridge: Cambridge University Press