

# **vection (self-motion perception) alters cognitive states, cognition of time, mental number line and personality**

**Takeharu Seno (seno@design.kyushu-u.ac.jp)**

Faculty of design, Kyushu University

4-9-1, Shiobaru, Minami-ku, Fukuoka, Japan

**Shuichiro Taya (s.taya@qmul.ac.uk)**

School of Biological and Chemical Science, Queen Mary Collage,

University of London, Mile End Road, London E1 4NS

**Yuki Yamada (yamadayuk@gmail.com)**

Faculty of Human-Environment Studies, Kyushu University

6-19-1 Hakozaki, Higashi-ku, Fukuoka Japan

**Keiko Ihaya (ihayakk@gmail.com)**

Faculty of Human-Environment Studies, Kyushu University

6-19-1 Hakozaki, Higashi-ku, Fukuoka Japan

**Hiroyuki Ito (ito@ design.kyushu-u.ac.jp)**

Faculty of design, Kyushu University

4-9-1, Shiobaru, Minami-ku, Fukuoka, Japan

**Shoji Sunaga (sunaga@ design.kyushu-u.ac.jp)**

Faculty of design, Kyushu University

4-9-1, Shiobaru, Minami-ku, Fukuoka, Japan

## **Abstract**

We examined the relationship between cognitive states and visually-induced self-motion perception, i.e. “vection” (latency, duration and magnitude). It is often anecdotally reported that time experienced in return travel (back to the start point) seems shorter than time spent in outward travel (travel to a new destination). Here, we report the first experimental results showing that return travel time is experienced as shorter than the actual time because of perceivingvection. Secondary, we explore how numbers are represented in depth in our mental space, we asked participants to sequentially speak random numbers while they observed forward/backwardvection. We found that participants tended to generate larger numbers when they perceived backward self-motion. Finally, We found that all the measures ofvection correlated negatively with the degree of narcissistic traits of participants.

**Keywords:** vection, time perception, mental number line, personality

## **Introduction**

Self-motion perception as determined by vision alone is called ‘vection’ (e.g. Fischer & Kornmüller, 1930). Stimulus attributes for effectivevection induction have been extensively studied (Seno et al., 2009). Recently, the relationships betweenvection and cognition were examined. Vection and attention (Seno et al., 2011a), time perception (Seno et al., 2011b), cognitive bias (Palmisano & Chan,

2004), quantity perception (Seno et al., 2011c) and personality (Seno et al., 2011d) have been reported. In this article we introduce our three examples thatvection alters cognitive states. Those examinations have not been conducted before. Our experiments were the first challenges ofvection and multi dimensional human cognition.

## **Time perception andvection**

A number of factors have been known to modulate the subjective duration of the interval in time, e.g., attention to time passage (e.g. Zakay & Block, 1997), subjective event number in the stimulus presentation period (Poynter, 1989), whether the task is prospective or retrospective (e.g. Doob, 1971) and the boredom impatience and anticipation (Brown, 1985). Adding a dual task (in addition to the evaluation of the interval time) increases the errors and decreaseS the accuracy of evaluation (Brown, 1997 review). As a new factor of determining experienced time, we show that a return travel is perceived shorter in time than an outward travel. We succeeded in showing thatvection strength modulate the shrinkage of the return travel. This was a very new finding.

## **Method**

We presented participants with virtual travel from Fukuoka, Japan, to a world-famous city, such as Paris, and examined subjective durations of stimulus movies, i.e. expanding-

optic-flow or dynamic-random-dot (DRD). We presented expanding flow during both the outward and return travels under the optic-flow condition. A round trip was assigned a cover story. Before the movie presentations, subjects understood that they would be asked to estimate the time durations of the stimulus presentation. We stated “Now we will go to Paris from Fukuoka” before the first stimulus presentation (outward trip). After the first stimulus presentation and before the second stimulus presentation, we stated “Now we will go back to Fukuoka from Paris” (return trip). Stimulus images were presented on a display with  $1,024 \times 768$  pixel resolution and at 75 Hz refresh rate. Each optic-flow display consisted of 16,000 randomly placed white dots on a black background. The dots were uniformly distributed within a simulated cube which subtended 72 (horizontal)  $\times$  57 (vertical) deg in visual angle. The stimuli were displayed on a 50-inch plasma display, with a viewing distance of 57 cm. The optic-flow simulated the forward or backward self-motion in constant-velocity (16 m/s). The DRD was refreshed at 75 Hz and the numbers of the dots were also 16,000. Twenty undergraduate students participated in each condition. The physical duration of stimulus presentations was 40 sec. Subjective durations were orally reported.

There was additionally the static-plane condition. A static random-dot plane was virtually placed 30 cm farther than the optic-flow plane (Figure 1). The farther dot plane effectively inhibited self-motion perception (e.g. Seno et al., 2010).

There were three stimulus conditions, optic flow, DRD and the static-plane conditions. The expectedvection strengths were strong, medium and nothing for optic flow, static-plane and DRD conditions respectively. The destination of the trip was randomly chosen from ten very famous world cities (e.g. New York, Tokyo, etc.). The expectedvection strengths for the three conditions were estimated from our previous study (Seno et al., 2010). Those subjective strength were 60, 40, 0 for optic flow, Static plane, and DRD respectively (100 was very strongvection and 0 was novection).

## Results and discussion

In the optic-flow condition, return travel was perceived as 5 sec shorter than the 40-sec physical presentation duration ( $Z=6.49$ ,  $p<0.01$ ). In the static-plane condition, the estimated duration in return travel was slightly longer than that; however, it was still shorter than 40 sec ( $Z=3.02$ ,  $p<0.05$ ). In the DRD condition, there was no shrinkage of the return travel.

We plotted the differences in subjective durations between outward and return-travel trials (Figure 2). Positive values indicated subjective time shortening in return travel for the round-trip conditions. Only in the optic flow and static-plane conditions, those values were significantly larger than 0 ( $z=11.97$ ,  $4.83$ , respectively,  $p<0.01$ ). That is, return travel was perceived as significantly shorter than outward travel in the two conditions.

Perceived time shrinkage was induced by perceivingvection. The degree of the shrinkage was correlated to the strength ofvection. Miles et al. (2010) reported that, depending on thevection direction, daydreaming was oriented to the future or the past. Considered together with our results,vection seems to have some power to alter cognition.

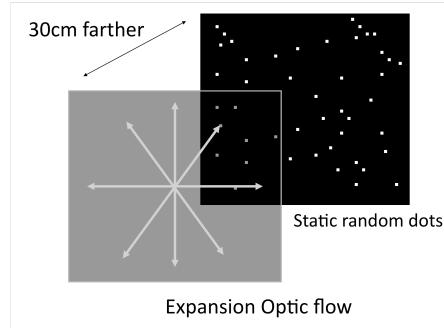


Figure 1. A schematic illustration of the farther-plane condition.

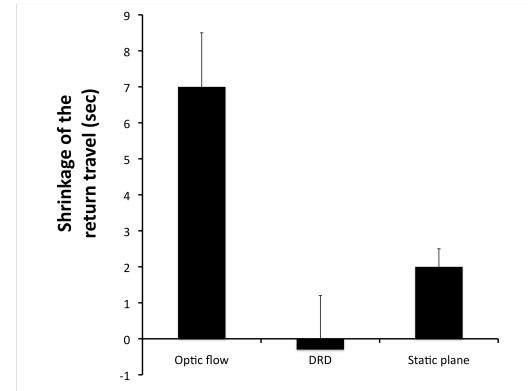


Figure 2. The shrinkage of the return travel. Error bars indicate SEM.

## Mental number line andvection

Previous studies have revealed a close connection between the representation of numbers and space (see Hubbard et al 2005 for a review); numerical magnitudes are represented in a mental number line (MNL) in an ascending order from left to right (e.g. Dehaene et al 1993) and from bottom to top (e.g. Schwarz and Keus 2004).

The representation of MNL is tightly linked with our body motion. For example, Loetscher et al (2008) asked participants to generate random numbers orally whilst turning their head, and found that participants generated ‘small’ numbers more frequently when they turn their head to the left than to the right. A correlation between the magnitude of generated numbers and the direction of saccades has also been reported (Loetscher et al 2010): participants made rightward saccades just before they generated the larger numbers while they made leftward saccades when generated the smaller numbers.

Previous studies have only examined the MNL on the 2D plane. The goal of this study was to explore space-number interaction in the front-rear direction by using inducedvection. Specifically, we asked participants to complete the random number generation task whilst they perceived the forward/backward body motion induced by expanding/contracting optic flows. This challenge was quite new and there has never been such study.

## Method

In each trial, whilst observing the optic-flow, the participants had to report orally four different numbers. Instruction was given as follows: "Please speak four different numbers in the interval between 0 to 100 as random as possible." To make sure of the occurrence ofvection, there was a 10 s interval between stimulus onset and the start of the task (for the delay ofvection induction). Ten participants generated 8 numbers (4 x 2 trials) and the other ten participants generated 16 numbers (4 x 4 trials) for each direction of the optic-flow. The expanding and contracting trials were randomized. Twenty participants observed optic-flows in a dark chamber.

The perception of optic flow-inducedvection was verified in a separate session after conducting the number generation session, when the magnitude and duration ofvection with the same visual stimuli was measured.

## Results and discussion

The average of the generated numbers was significantly larger with the contracting motion than with the expanding motion (two-tailed paired t-test:  $t_{19} = 2.83$ ,  $p < .05$ ) (Figure 3). We found no bias such that observers generated numbers in an ascending or a descending sequence. The results showed that the sensation of self-motion could bias the magnitude of generated numbers, suggesting that, together with the previous results (Loetscher, et al. 2008, 2010), the representation of numerical magnitudes is tightly linked with our body motion. The present results suggest that the smaller numbers are represented in a front space while the larger numbers are represented in a rear space.

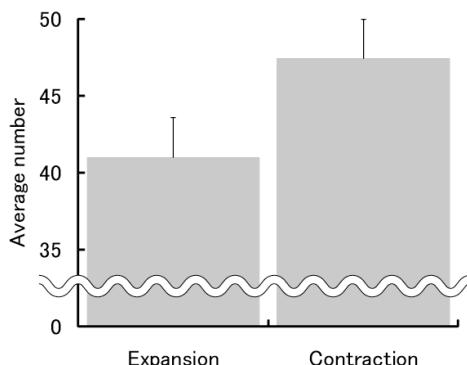


Figure 3. The average of generated numbers. Error bars indicate SEM.

## Personality

In our previous studies, we noticed that there were considerable individual differences betweenvection latency, duration and magnitude. Moreover, these individual differences appeared to be consistently exhibited, regardless of the stimulus conditions, i.e. an observer who perceived longer and strongervection in one experiment also perceived longer and strongervection in othervection experiments. These observations suggest thatvection correlates with long-lasting characteristics of the participants. It has been reported that some cognitive abilities correlate with properties of personality (DeYong et al., 2005). For example, the performance of mental rotation (Ozer, 1987) or the magnitude of the attentional blink (McLean & Arnell, 2010) correlated with personality. A positive affectation influences performance in a variety of cognitive tasks (Ashby et al., 1999). The 'Big Five' factors of personality (openness, conscientiousness, extraversion, agreeableness, neuroticism) have also been found useful in predicting some everyday behaviors (Paunonen and Ashton, 2001). Therefore we thought thatvection might also correlate with the personality traits of participants. We believe that the personality is one important aspect of human cognition. Thus this examination was one new challenge forvection and cognition.

## Method

We used an optic flow of expansion asvection stimulus. The duration of the stimulus was fixed at 40 seconds. Thirty adult volunteers participated in the experiment. Eight trials were conducted and the observers were asked to press a button when they perceived self-motion. At the end of each trial, the observers were also instructed to rate the subjective strength ofvection using a magnitude estimation on a scale from 0 (novection) to 100 (very strongvection).

After thevection task, the observers completed three questionnaires. The first included scales of public and private self-consciousness, which were Japanese versions of Fenigstein's original index (Sugawara, 1984; Fenigstein et al., 1975). The second was the Narcissistic Personality Inventory Short Version (NPI-S; Oshio, 1999), based on the Narcissistic Personality Inventory developed by Raskin and Hall (1979). The third was related to the Big Five personality factor scales (Japanese version by Saito et al., 2001).

## Results and discussion

The results of thevection study were consistent with those found in our previous studies (the averagevection latency, duration and magnitude were 12.25 seconds, 21.98 seconds, and 38.74, respectively), confirming the validity of thevection measures. Vection latency and total-NPI-S score were positively correlated ( $r^2 = 0.47$ ,  $p < 0.0001$ ), whereas duration or magnitude and total-NPI-S score were negatively correlated ( $r^2 = 0.28$ ,  $p < 0.003$ ;  $r^2 =$

0.19,  $p < 0.02$ , respectively) (Figure 4). No other comparisons between the threevection measures and personality scale scores showed any significant correlations.

We found that the more narcissistic the observer was, the weaker the perception ofvection was.

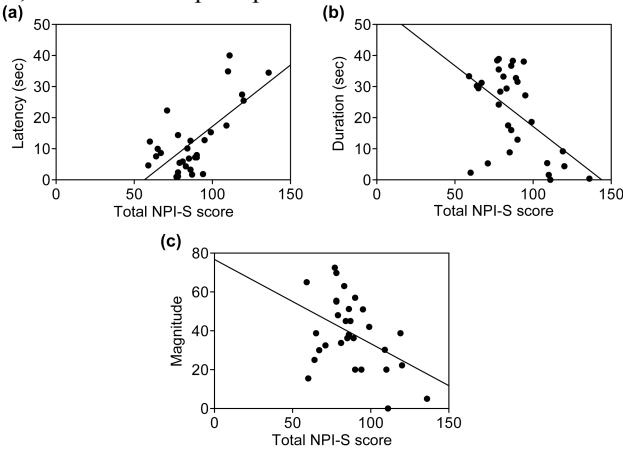


Figure 4. Correlations between vection measures (a: latency; b: duration; c: magnitude) and total-NPI-S score.

## Conclusion

We here showed three examples that vection alters our cognitive states. They were all new findings. Vection induced shrinkage of time of the return travel. Vection revealed our mental number line in depth. Vection and personality were correlated. Further examinations of the relationship between vection and cognitive states should be done in the future.

## Acknowledgments

The first author was aided by Japan Society for Promotion of Science.

## References

- Ashby FG., Isen Am., Turken AU. 1999 "A Neuropsychological Theory of Positive Affect and Its Influence on Cognition" *Psychological Review* **106** 529-550
- Brown, SW. 1985 "Time perception and attention: The effects of prospective versus retrospective paradigms and task demands on perceived duration." *Perception and Psychophysics* **38** 115-124
- Brown, SW. 1997 "Attentional resources in timing: Interference effects in concurrent temporal and nontemporal working memory task" *Perception and Psychophysics* **59** 1118-1140.
- Doob, LW. 1971 "Patterning of time" New Haven: Yale University Press.
- Fenigstein A, Scheier M E, Buss A H, 1975 "Public and private self-consciousness: Assessment and theory" *Journal of Consulting and Clinical Psychology* **43** 522-532
- Fischer M H, Castel A D, Dodd M D, Pratt J, 2003 "Perceiving numbers causes spatial shifts of attention" *Nature Neuroscience* **6** 555-556
- Hubbard EM, Piazza M, Pinel P, Dehaene S, 2005 "Interactions between number and space in parietal cortex" *Nature Review Neuroscience* **6** 435-448
- Loetscher T, Schwarz U, Schubiger M, Brugger P, 2008 "Head turns bias the brain's internal random generator" *Current Biology* **18** R60-62
- Loetscher T, Bockisch C J, Nicholls M E R, Brugger P, 2010 "Eye position predicts what number you have in mind" *Current Biology* **20** R264-265
- Miles, LK., Karpinska, K., Lumsden, J., Macrae, CN. 2010 "The meandering mind: Vection and mental time travel" *PLoS One* **5**:e10825
- Oshio A. 1999 "Narcissistic personality and friendship in high-school students" *The Japanese Journal of Personality* **8** 1-11 (in Japanese)
- Ozer, DJ. 1987 "Personality, Intelligence, and Spatial Visualization: Correlates of Mental Rotations Test Performance" *Journal of Personality and Social Psychology* **53** 129-134
- Paunonen SV., Ashton MC. "Big five factors and facets and the prediction of behavior" *Journal of Personality and Social Psychology* **81** 524-539
- Palmisano, S, Chan, AY. 2004 "Jitter and size effects onvection are immune to experimental instructions and demands" *Perception* **33** 987-1000
- Poynter, D. 1989 "Judging the duration of time intervals: A process of remembering segments of experience. Time and human cognition: A life-span perspective" *Advances in Psychology* **59** 305-33
- Raskin RN., Hall CS. 1979 "A narcissistic personality inventory" *Psychological Reports* **45** 590
- Zakay, D. Block, RA. 1997 "Temporal cognition" *Current Directions in Psychological Science* **6** 12-16.
- Dehaene S, Bossini S, Giraux P, 1993 "The mental representation of parity and numerical magnitude" *Journal of Experimental Psychology: General* **122** 371-396
- Saito, T., Nakamura, T., Endo, T., & Yokoyama, M. 2001 "Standardization of Big Five scales using the adjective check list" *Kyushu University Psychological Research* **2** 135-144 (in Japanese)
- Schwarz W, Keus I M, 2004 "Moving the eyes along the mental number line: comparing SNARC effects with saccadic and manual responses" *Perception & Psychophysics* **66** 651-664
- Seno, T., Ito, H. & Sunaga, S. 2009 "The object and background hypothesis forvection" *Vision Research* **49** 2973-2982
- Seno, T., Ito, H., Sunaga, S., 2010 "vection aftereffect from expanding/contracting stimuli" *Seeing & Perceiving* **23** 273-294
- Seno T, Ito H, Sunaga S, 2011a "Attentional load inhibitsvection" *Attention, Perception & Psychophysics*.
- Seno T., Ito H., Sunaga S. 2011b "Self-motion perception compresses time experienced in return travel" *Perception* **40** 497-499
- Seno T., Taya S., Ito H., Sunaga S. 2011c "Mental number line in depth revealed byvection" *Perception*, **40**, 1241-1244.
- Seno, T., Yamada, Y. & Ihaya K. 2011d "Narcissistic people cannot be moved easily by visual stimulation" *Perception*, **40**, 1390-192
- Sugawara K. 1984 "An attempt to construct the self-consciousness scale for Japanese" *Japanese Journal of Psychology* **55** 184-188 (in Japanese)