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

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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 perceiving vection. 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/backward vection. We found that participants tended to generate larger numbers when they perceived backward self-motion. Finally, We found that all the measures of vection 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 effective vection induction have been extensively studied (Seno et al., 2009). Recently, the relationships between vection and cognition were examined. Vection and attention (Seno et al., 2011a), time perception (Seno et al., 20011b), 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 that vection alters cognitive states. Those examinations have not been conducted before. Our experiments were the first challenges of vection and multi dimensional human cognition.

Time perception and vection

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 that vection 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 × 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) x 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 expected vection 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 expected vection 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 strong vection and 0 was no vection).

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

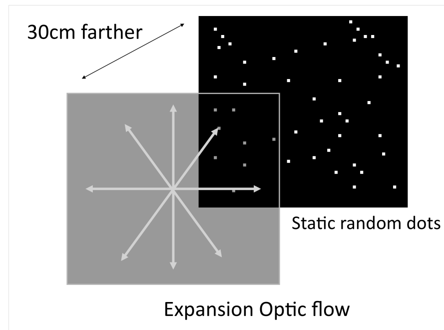

Figure 1. A schematic illustration of the farther-plane condition.

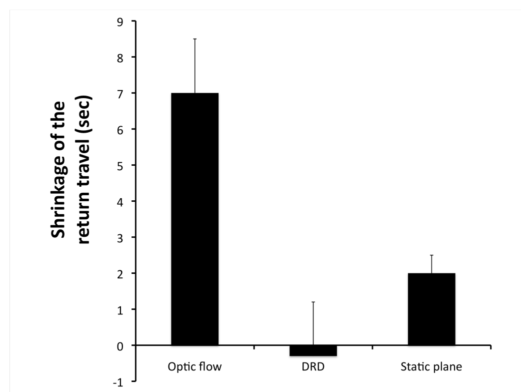

Figure 2. The shrinkage of the return travel. Error bars indicate SEM.

Mental number line and vection

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. Dehane 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 induced vection. 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 of vection, there was a 10 s interval between stimulus onset and the start of the task (for the delay of vection 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-induced vection was verified in a separate session after conducting the number generation session, when the magnitude and duration of vection 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.

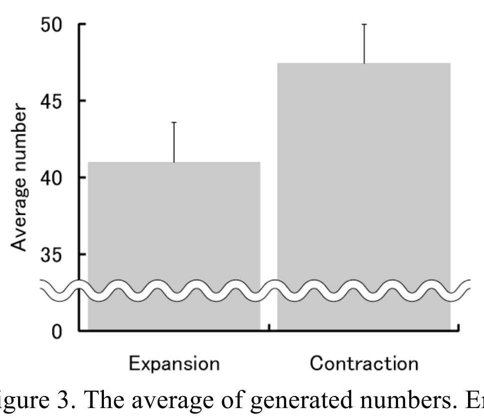

Figure 3. The average of generated numbers. Error bars indicate SEM.

Personality

In our previous studies, we noticed that there were considerable individual differences between vection 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 stronger vection in one experiment also perceived longer and stronger vection in other vection experiments. These observations suggest that vection 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 that vection 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 for vection and cognition.

Method

We used an optic flow of expansion as vection 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 of vection using a magnitude estimation on a scale from 0 (no vection) to 100 (very strong vection).

After the vection 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 the vection study were consistent with those found in our previous studies (the average vection latency, duration and magnitude were 12.25 seconds, 21.98 seconds, and 38.74, respectively), confirming the validity of the vection 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 three vection measures and personality scale scores showed any significant correlations.

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

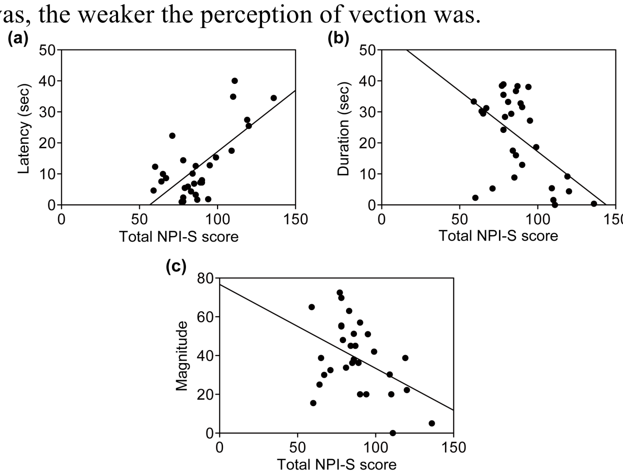

Figure 4. Correlations between vection measures (a: latency; b: duration; c: magnitude) and total-NPI-S score.

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.

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