The Effect of Physical Load on the Cognitive Process of Estimation

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Abstract

The purpose of this study was to examine the process of embodied cognition in distance estimation. According to recent cognitive science studies, our intelligent behavior that ranges from perception to inference is not accomplished in only a closed mental process, but is affected by body and action. However, previous studies do not clarify whether these effects were derived from physical load or subjective heaviness. In order to examine the question, two experiments were conducted using the ''size-weight illusion''. Performance on the distance estimation task was not affected by subjective heaviness but by physical load.

Keywords: embodied cognition; size-weight illusion; distance estimation

Introduction

We examined the contribution of the physical body on higher-order cognitive processing. Recently, in cognitive science, studies have reported that a wide range of intellectual behavior, from perception to inference, is not only a closed mental process but is also subject to influences of the physical body and its actions/motions(Wilson, 2002; Gibbs, 2005; Proffitt, 2006). Since physical loading is known to exert effects on mental processes, Narukawa, et al. (2010) reported changes in gustatory sensation that accompany the degree of fatigue. Krishna & Morrin (2008) showed that the sense of hardness of the bottle affected the evaluation of mineral water. Bhalla & Profitt (1999) demonstrated experimentally that different estimates are made of the inclination of a sloped path under the conditions of carrying a load on the back versus being empty-handed. In addition, in the study by Ackerman, Nocera & Bargh (2010), the curriculum vitae of a fictitious person bound to two types of clipboards that differed in heaviness were handed to the subjects, who were asked to make evaluations of the person. The evaluations made by those of the group handed the heavier clipboard were higher than that of the group handed the lighter clipboard. The results of these prior studies suggest that mental processes are influenced by loading and fatigue of the physical body of the subject. However, it has not been clarified whether these effects were due to the amount of actual physical load or due to the amount of the subjective load. In this study, this issue was examined using a distance estimation task adopted from a prior study. If the effects were due to the amount of the physical load, then physical/non-overt processes, which are separate from the subjective view of the subject, are expected exert an effect on the inference. Conversely, if they are due to the amount of the subjective load, it may be considered that the subjective view of the subject and overt processes exert the effects on the inference.

To examine these physical and subjective loads separately, the ''size-weight illusion'' (Charpentier, 1891) was used in this study. This illusion occurs when if the weights of two objects are the same, the larger object is sensed as being lighter. Utilizing this illusion, distance estimation tasks under conditions of being subject to different subjective loads while being subject to the same physical load (Experiment 1) and distance estimation tasks under conditions of being subject to different physical loads while being subject to the same subjective load (Experiment 2) were conducted to examine the effect of the physical and subjective amount of the physical load.

Experiment 1

In Experiment 1, experimental manipulations were conducted to generate the subjective view that loads with different weights were being exerted while the same weight physically was exerted, and distance estimation tasks were conducted under conditions of a divergence between the amount of subjective and physical load. This was used to examine how the perceived load of the weight exerted on the body is processed.

Method

Subjects Ninety-two college students participated in the experiment. Of them, 24 were assigned to the 10 L group, in which the subject held a 5 kg tank with capacity of 10 L as the number of steps of a stairway was estimated; 33 were assigned to the 20 L group, in which the subject held a 5 kg tank with a capacity of 20 L as the estimation was made; and 35 were assigned to the control group, in which they made the estimation without holding any weight. A single-factor between-subjects design was used in this experiment.

Task A revised form of the distance estimation task published by Bhalla & Profitt (1999) was employed. In the revised form, a picture of the up-bound steps of the Atago Shrine (Fig. 1) was presented for 5 s, and the subject was

Figure 1. The up-bound steps of the Atago Shrine

instructed to estimate the number of the steps. The picture was displayed on a 17-in XGA display placed at a height of 160 cm. With regard to the physical loads to be exerted on the subjects, we prepared a reference weight with 5 kg of water in a polyethylene tank with a capacity of 5 L, and the weights for those assigned to the groups other than the control group (5 kg with a size of 10 L, or 5 kg with a size of 20 L).

Procedure For each group, the subject was first handed the reference weight and was told that its weight was 5 kg. Next, the weight assigned to each group for the distance estimation task was given, and the task of estimating the number of steps was performed with subject holding the reference weight with both hands. The up-bound steps of the Atago Shrine were present to the subject for 5 s; then the estimation was given orally while holding the weight. The subjects were told to respond immediately without thinking deeply when providing their oral response. Following this, they were asked to estimate the weight of the tanks.

Results

First, the values of the weight of the tanks used for the estimation task predicted by the 10 L group and by the 20 L group are discussed. The value was 5.94kg for the 10 L group and 4.06kg for the 20 L group. A significant difference was found between the two groups ($t(26) = 2.74$, $p < 0.05$, $r = 0.470$, Fig. 2). This result confirmed that a size-weight illusion effect had occurred for members of the 10 L and 20 L groups. he estimates of the distance of the steps was 52.79 steps for the 10 L group and 49.88 steps for the 20 L group.

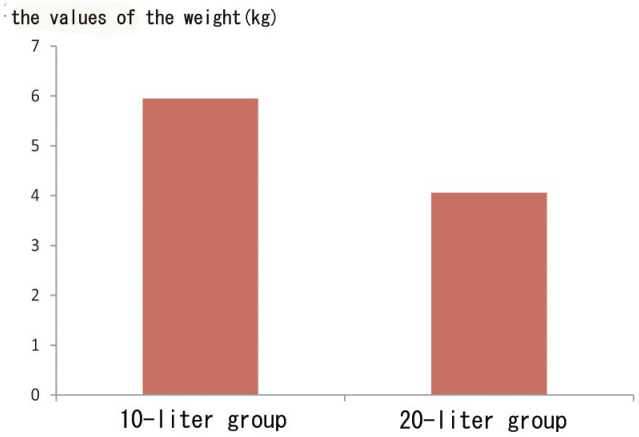

Figure 2: The values of the weight of the weights used in Experiment 1

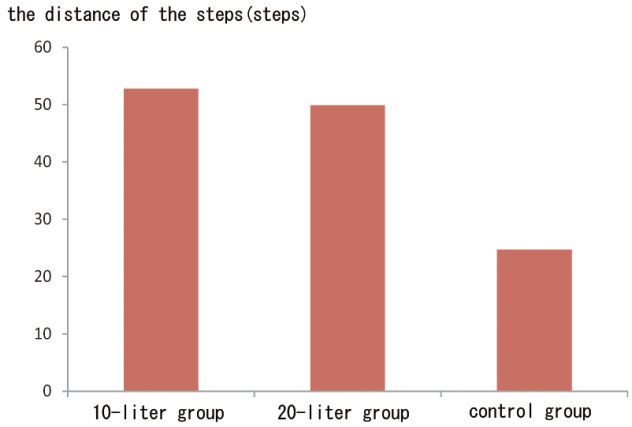

Figure 3: The estimated distance of the steps in Experiment 1

A one-way ANOVA revealed a main effect for the weight factor ($F(2,89) = 14.82$, $p < 0.01$, $\eta^2 = 0.25$, Fig. 3). Multiple comparisons (Bonferroni's method) revealed significant differences between the control group and the other two groups ($p < 0.01$) but not between the 10 L and the 20 L groups.

Experiment 2

The results of Experiment 1 suggested that a difference in perceived weight did not affect the estimate of the number of steps but instead the physical loading affected the distance estimations. However, the conclusion that the subjective amount did not affect the estimates, runs contrary to the finding that no significant difference was observed between the 10 L and 20 L groups. Therefore, in Experiment 2, the self-adjustment of the amount of loading by the subject was performed using the point of subjective equality(PSE) measurement procedure, and comparisons were made for cases in which physically different loads were exerted whereas the subjective load was the same.

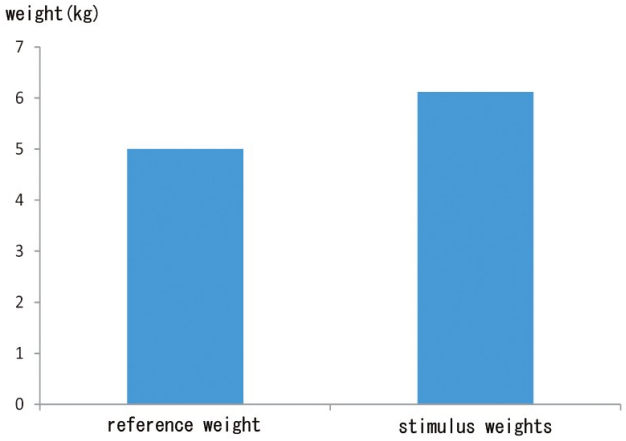

Figure 3: The values of the weight of the tanks used in Experiment 2

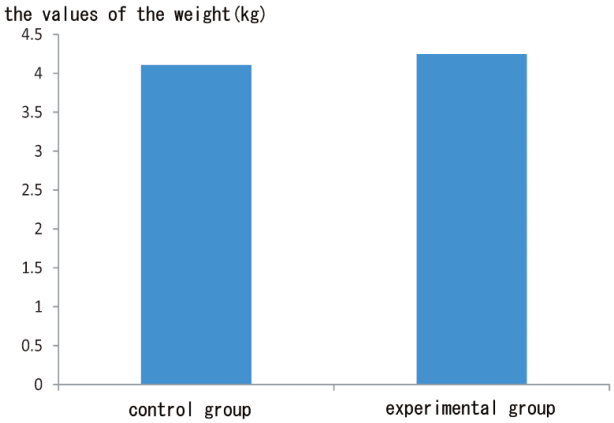

Figure 4: The subjective weight of the tanks in Experiment 2

As in Experiment 1, if the effects on the estimates were due to the physical load and not due to the subjective load, significant differences should be observed between the estimates.

As, in Experiment 1, the subjects were asked to estimate the number of steps, but it was difficult to predict whether the number is over-estimated or under-estimated by the physical loading in comparison to the previous studies since the correlations between the number of steps and the distances and inclinations reported by those studies cannot be guaranteed. Thus, in Experiment 2, they were instructed to estimate the distance, and not the number, of the steps.

Method

Subjects Twenty-seven college students participated in the experiment. Of them, 14 were assigned to the experimental group and 13 were assigned to the control group. A single-factor between-subjects design was used for the experiment.

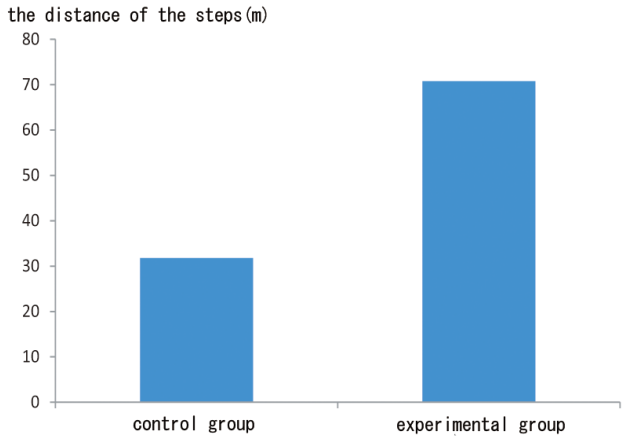

Figure 5: The estimated distance of the steps in Experiment 2

Task The same distance estimation task was employed as in Experiment 1. With regard to the physical loads to be exerted on the subjects, after having the reference stimulus of a polyethylene tank with a capacity of 5 L containing 5 kg of water presented to them, they were asked to, by themselves, adjust the amount of physical loading by using the PSE measurement procedure. In accord with this procedure, the subjects put water into a polyethylene tank with a capacity of 20 L for the stimulus weight until they thought it to be identical in weight as that of the reference stimulus. The average weight of the stimulus weights set by the subjects was 6.36 kg, which was more than 1 kg heavier than the reference weight (Fig. 3). The subjects were not informed that the reference weight was 5 kg, and were only aware that the adjusted weights have the same weight as the reference weight.

Procedure In each group, the subject was first asked to perform the adjustment of the weight in accordance with the PSE procedure. Subsequently, tasks of estimating the length of the steps were performed with the self-adjusted weight, in the case of the experimental group, and with the reference weight, in the case of the control group, held in both hands. As in Experiment 1, the up-bound steps of the Atago Shrine were presented to the subject for 5 s. Next, each of the subjects provided their estimates orally while still holding the weight. Following this, the weight used for the distance estimation task was also estimated.

Results

First, the predicted values of the weight of the reference weight are discussed. The mean value was 4.11 kg for the control group and 4.25 kg for the experimental group. No significant difference was found between the two groups ($t(25) = 0.26$, $p = 0.79$, n.s., $r = 0.05$, Fig. 4).

Based on this result, the possibility that the sense of weight was significantly different between those in the control group and those in the experimental group was rejected.

The estimate of the distance of the steps was 31.79 m for the control group and 70.77 m for the experimental group. A significant difference was found between the two groups ($t(25) = 2.65$, $p < 0.05$, $r = 0.47$, Fig. 5).

Discussion

In the present study, the result of experiments using distance estimation tasks accompanied by physical loading using the size-weight illusion showed that the effects of physical loading on mentation are due to physical load rather than subjective load. The subjects in the control group in Experiment 2 estimated the length of the steps while holding a 5 kg weight that they thought weighted 4 kg, and the subjects in the experimental group while holding a 6 kg weight that they thought was 4kg. The difference between their length estimates of the two groups suggests that their estimations were being influenced, not by how heavy they thought the weights were, but rather by the actual physical load exerted on the body. This also suggests that a load that is exerted on the body may play an implicit role in making inferences and judgments.

Unlike previous studies, a picture of stairs was used in the present study instead of an actual environment. Nevertheless, physical loading affected the participants' distance estimation. This shows robustness of the previous studies, and suggests that participants mentally simulate action with reference to physical load.

Future Issues

Although physical loading exerted effects in a manner that did not reach the subjective level, it is not possible to conclude that the amount of subjective load did not exert any effect at all. Further, many aspects of the process by which physical loading influenced the estimation have yet to be elucidated. It is necessary to consider the mutual relationship of and processing between the subjective load and the physical load.

In the present study, the estimates were made when the individuals were subjected to a physical load, but it is not known to what extent the effects were sustained. As indicated by previous studies, fatigue influences inference. The degree of fatigue and the extent of recovery are expected to also influence the duration for which the effects are sustained.

In addition, the duration of the presentation of the object to be estimated warrants some discussion. In this study, the stimulus was presented for a limited duration of 5 s. The subjective level could become dominant in processing when the object of the estimation is presented for longer duration. Moreover, many issues remain with regard to the mutual relationship between the top-down processing of the subjective view and the bottom-up processing from the physical body.

In the literature of the cognitive process of metaphor, it is thought that metaphors enable us to think about concepts on the basis of concrete sensorimotor experiences. Previous studies suggested that a conceptual representation was linked to some somatic and physical state by some metaphorical concept (Clark, 1973; Lakoff & Johnson, 1980). Researchers who investigated the haptic priming effect found evidence to support that idea (Williams & Bargh, 2008; Ackerman, Nocera & Bargh, 2010). In future studies, the effects of physical load on conceptual representation should be examined.

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