PEOPLE USE EMBODIED REPRESENTATIONS NEVERTHLESS THEY MAY USE DIFERENRT STRATEGIES IN PROBLEM SOLVING

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Abstract: *In their classical study, Sheppard and Metzler (1971) demonstrated that the speed of mental rotation of objects is linearly proportional to the angle that the objects should be rotated. However, Flusberg & Boroditsky, (2011) assume that depending on the instruction distinct processes take part in mental rotation task. The results of their empirical study usually are interpreted in favor of necessity to assume that dual processes (and hence dual representations) exist in human cognitive system. We conducted an experiment that confirms the hypothesis that different strategies, not different processes underlie the results of Flusberg & Boroditsky, (2011).*

Nevertheless that the topic may seem too specialized, it supports the embodied view to human cognition. In this way, the findings have not only theoretical merits, but can be of high interest for education planning. Studying the effects of the body on the mind contributes the education planning and has an increasing role in mathematics education and problem solving issues in high school, college and beyond.

Keywords: EMBODIMENT, MENTAL ROTATION

1. Introduction

Often we deal with images constructed by our mind, rather than based on information coming from the environment. People can easily construct mental images of objects that had never seen before. Everybody can imagine, for example, a flying pink elephant or a dog with six feet.

People use mental images and diagrams also for planning actions and for problem solving. In addition, the mental images often are not static but dynamic – whole situations can be played mentally, including movements, actions, and their result.

Many evidences point out that part of the representations of our own real actions and their mental pictures share same areas in the visual and motor brain zones. For example, Kosslyn et al. (2001) demonstrated that one and the same brain zones in the primary motor cortex are active if people actually perform concrete actions or if they imagine themselves doing them. When people are reasoning or planning actions, they manipulate objects in their visual mental images in the same way as being actual objects (Shepard & Cooper, 1982). When people observe human faces or places, the same zones of the visual cortex are active, as if they imagine these faces or places (O'Craven & Kanwisher, 2000). Those findings are in congruence with the idea that mental imagery share same neural substrate involved in perception (Kosslyn et al., 2001).

Using Positron Emission Tomography (PET), Parsons (1995) demonstrated that people find it difficult to imagine body parts to be moving in an unnatural manner, because the participants implicated their own experience with their body and the way they move it. Motor strategies are used not only for mental rotation of body parts, but for non-bodily objects as well (Cohen et al., 1996; Carpenter et al., 1999).

In parallel with the brain imaging studies, many behavioral experiments show converging results. The time needed to imagine an action correlates with the time needed to perform it actually (Decety & Michel, 1989; Landauer, 1962). Moving hands from resting posture to another posture takes equal time as to imagine those movements (Parsons, 1994). However, the imagination seems to be restricted from our attitudes as well. If people expect that a certain task would be easier if using a tool, then in an imagery task of the same problem, they imagine performing an action to take less time than it took them actually (Osiurak, et al., 2014). In addition, it is found out that we can act in a previously studied environment even with blind folded eyes using the mental representation of the environment (Decety et al., 1989). A lot of research supporting the embodied view of the mental representations is in accordance with the idea for shared representations of real and imagery actions; for example, people perceive a certain distance as longer if they are with a heavy backpack on their back (Proffitt et al., 2003).

2. Mental rotation of pictures of easily and hardly for actual rotation objects

In their classical study, Sheppard and Metzler (1971) demonstrated that the speed of mental rotation of objects is linearly proportional to the angle that the objects should be rotated.

It is easy to relate those findings to the results supporting the view for shared representations of imagery and real actions. One can conclude that the same processes serve for both. However, Flusberg and Boroditsky (2011) explored the question more detailed and found that the problem is more complicated. They were interested if the objects that are more difficult to physically manipulate are also difficult to mentally manipulate. In their experiment, they used Shepard-Metzler stimulus to study embodiment in motor and visual imagery. The experiment was designed in two parts. In the first part individuals physically manipulated wooden Shepard-Metzler figures, half of them were heavy (filled with sand), and the rest were light (empty). In the second part of the study, the participants were solving the classical mental rotation tasks – they should answer whether the left one of two projected objects is the same like the right one, if rotating it on a certain angle. Participants were instructed to imagine that they are grasping one of the objects with their hand and turning it until it aligns with the other object. With such instruction, the motor imagery is involved and results had shown that objects, which are more difficult for physical manipulation, were also more difficult for the mental rotation (i.e., mental rotation takes more time). The finding was that people mentally rotated the heavy objects slower than the light ones. However, in their next experiment, the researchers involved the visual imagery by asking participants to imagine that one of the objects is rotating by itself until it aligns with the other. With this different instruction, relation between the reaction time in the mental manipulation and easiness in the physical manipulation was not detected. Similar findings were reported by Kosslyn et al. (2001). When people are instructed to imagine that they rotate certain objects, the motor cortex, including M1 region, is activated, as well as it is if they actually rotate them.

However, when the instruction was to imagine the rotation performed by an external engine, there was not such activation.

These differences in results, depending on the instruction only, show that motor and visual imagery can be pulled apart. People's preceding motor experience is involved when they imagine performing an action (moving an object) themselves, but does not matter if they imagine the action is realized on its own (Flusberg & Boroditsky, 2011).

However, is it possible a representation of an image to rotate on its own? We could say that objects never rotate themselves on their own. Maybe participants find it easier to rotate the representation of the whole illustration of the image (paper or a computer screen) when the instruction has been to imagine that objects move by themselves. However, the weight of the paper or the computer screen is constant and does not depend on the image on it. Maybe people still do the mental rotation of the image representation but they probably manipulate it as a representation of a paper (or a computer screen) with the image on it. This strategy could be used if according to the instruction there is no need of performing explicit imaginary rotation of the object.

Thus, maybe the results obtained by Flusberg & Boroditsky (2011) do not necessary mean that motor and visual imagery can be pulled apart. Maybe people use different strategies depending on the instruction but both strategies include imaginary motor rotation. However, depending on the instruction, people either rotate the object itself, either the whole image on the screen. In the first case, the reaction time would depend on the weight of the object; in the second case – on the weight of the screen (equal for all stimuli).

We designed an experiment to test this possibility using instruction that does not assign any strategy to use for mental rotation when performing the task. As an attempt to avoid the potential possibility of mentally rotating the representation of the computer screen, instead rotating the representation exactly of the object on the image, we decided to put additional stimulus next to each target image. The additional object played a role of an "anchor", to hold the attention of the participants to the rotated stimulus.

3. Experiment – mental rotation of picture of heavy and light objects

Method

Design

The design of the experiment was 5x2 within subject factorial. The angle of rotation of the right object in the pair had five levels – 60^0, 120^0, 180^0, 240^0, and 300^0. There were two types of rotated objects – light ones and heavy ones. There was one dependent variable – the reaction time needed for the participants to answer whether the two objects on left were the same as the two objects on the right, no matter whether one of them is rotated.

Stimuli

We conducted a set of 40 images of different objects, separated into two groups – 20 heavy and 20 light objects. In order to ensure that this separation is generally accepted among people, we asked 10 experts to judge the weight of all objects on the pictures on a 7-point scale. We aggregated the judgments for each picture. The main judgments of the light stimuli was 1.27, std. dev. 0.624; 95% confidence interval (1.22 – 1.32). The main judgments of the heavy stimuli was 5.79, std. dev. 1.492, 95% confidence interval (5.67 – 5.91). The difference was so large that we concluded that people generally assume that the objects from the two subsets differ in their weight. All stimuli are presented in the Appendix.

The size of the pictures was set to be the same for all of the objects with the use of Photoshop.

Procedure and participants

Thirty participants (13 males and 17 females) volunteered to participate in the experiment. They were naive regarding the aim of the study. All subjects were right-handed with a range of ages from 19 to 34.

The task was presented on computer screen, using E- Prime software, in the Laboratory of Experimental Psychology of New Bulgarian University. Four objects were shown on the screen by each trial: from left to right – an anchoring object, a non-rotated test object; again the anchoring object, again the test object but rotated and it is either the same one, or mirrored one (see Figure 1). There was a distance between the left two objects and the right ones, thus the whole picture consisted of two pairs. In the right half of the right pair either the same (not mirrored) stimulus as the one in the right half of the left pair appeared or mirror-reversed copy of it, all rotated on different degrees - 60°, 120°, 180°, 240°, 300° clockwise (Figure 1). On the right side of the left pair was presented non-rotated 0° stimulus. Next to each (on left) of both objects was an "anchor" stimulus, which is an image of a tree. The purpose of the tree was to hinder the participants to rotate the whole right part of the image until it fits to the left part. Instead, we expected that the tree would foster the people to rotate mentally the test stimulus only.

Each participant solved 400 trials (5 angles x 40 objects x 2 conditions – mirrored or not). The order of trials was randomized for each subject. In the beginning of the experiment, each subject completed ten training trials.

Fig. 1 *An example of the stimuli used in the experiment. The target object – the lorry – was from the subset of the heavy ones. The correct response for this trial was "yes", because the rotated lorry (rotated on 120°) was not mirrored.*

Two keys of Response time button box device were marked with "Yes" and "No" labels.

Individuals were instructed to answer as quickly as possible by pressing the "Yes" button if the pair of images in the right part of the screen is the same, even if some stimuli are rotated, as the pair of images in the left and to press button "No" if they are different. In those cases when the rotated stimulus in right was mirror-reversed the right answer should be "No". If this stimulus is rotated but not mirror-reversed the right answer would be "Yes". Each subject gave consent to participate in the experiment by signing a form.

Reaction times for the responses were coded automatically.

Results

The first 10 trials from every subject were training and were removed. Then, the wrong answers (16%) were removed as well. The correct "No" responses were not analyzed. We took only the correct responses with answer "Yes".

The results were aggregated by median for each subject, each angle, and each weight of the mobile object.

Not surprisingly, there was a large significant effect of the angle: $F(4, 116) = 73{,}217$, $p<0.001$, $\eta 2 = 0.716$. It was, however, also a significant effect of the weight: $F(1, 29) = 7{,}391$, $p=0.011$, $\eta 2 = 0.203$. There was not a significant interaction: $F(4, 116) = 1{,}669$, $p=0.162$, $\eta 2 = 0.054$.

The difference of RT's for the heavy and the light stimuli for each angle was 136.097ms.

The results are visualized on Figure 2:

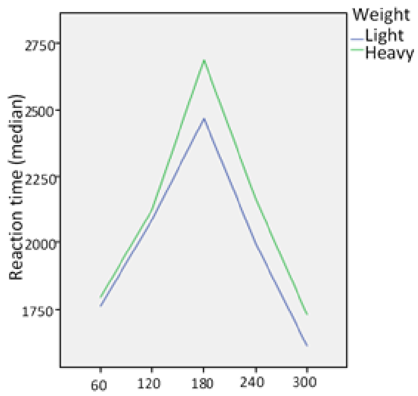

Fig. 2 *The median of the reaction times for light objects (blue line) and heavy objects (green line) for each angle of rotation.*

4. Experiment for controlling the speed for recognition of the stimuli

In order to test what is the eventual effect of the time needed for recognition of the stimuli, we conducted a control experiment. We exposed the same stimuli that were used in the main experiment to other thirty participants (17 males and 13 females). Subjects were asked to answer, as quickly as possible, with a "Yes" button if the objects on the left of the screen are the same as those in right and with "No" button if they are mirror-reversed. There were not any rotations. Each of the previously used stimuli was presented not rotated with its either same or mirror reversed copy, with the immobile anchoring stimulus (the three) to the left of each stimulus.

All of the participants in the experiment were right-handed with a range of ages from 19 to 33.

Each subject agreed to participate in the study by signing a form.

The reaction times of the responses were automatically coded.

Results

Following the same procedure like in the main experiment, we removed 6,4% wrong answers, took the right responses "Yes" only, and aggregated the medians of the RTs by subject and weight.

The aggregated median of the RTs for the light objects was 1142.72ms; for the heavy objects it was 1027.10ms. The difference was on account of the light objects and was significant ($t(29) = 2.605$, $p = 0.014$).

Actually, we expected that the difference between the stimuli would be not significant. In addition, we hoped that the confidence interval for the difference would be much smaller than the effect of the first experiment. Other results were realized. There was a difference in reaction times for the light and the heavy objects without any rotation. However, longer time was demonstrated for the light objects. Not just that the heavy objects were not harder for recognition, but exactly on the opposite – they were easier. Thus, the aim of this control experiment was achieved: the effect, obtained in the first experiment cannot be due to any differences of the recognition time of the stimuli.

5. Discussion

Flusberg and Boroditsky (2011) found that depending on the instruction, people use different processes for mental rotation. When they receive an explicit instruction to imagine how they grasp and rotate the objects with their hands, then people mentally manipulate slower the objects, which are heavier for actual manipulation. However, when the instruction was to imagine that the objects rotate by themselves, then the effect disappeared.

However, the object cannot rotate by itself, with a magical engine. Thus, we supposed that maybe people use different strategies, not different processes for mental rotation. Maybe people are able to imagine how they manipulate the objects on the screen; or they are able to imagine how they rotate the whole screen or a part of it too.

We conducted an experiment, trying to avoid the possibility for the participants to rotate mentally just a part of the screen. We added an immobile anchoring object to the left of the test stimuli. Of course, theoretically, again it is possible people to manipulate mentally a small fraction of the screen only; however, it is much more difficult.

Thus, we tested whether even if there is no explicit instruction to the people to imagine how they manipulate the objects with their hands, they will react to a mental rotation task for the heavy objects slowly than for the light ones.

Contrary to the results of Flusberg and Boroditsky (2011), we obtained a significant difference in the reaction time needed to mentally rotate heavy objects then light ones, regardless of the neutral instruction. Our explanation of both the results from this experiment and the findings of Flusberg and Boroditsky (2011) is that people may use different strategies for mental rotation but not different processes. Depending on the instruction, people may try to mentally rotate either the objects on the picture, or the entire picture.

There was an alternative explanation of the results from this experiment. Regardless that many stimuli were used (20 heavy and 20 light ones), maybe just the mean time for recognition of the heavy stimuli was higher. In order to control this, we obtained a second experiment, in which there was not rotation required. People should just say whether the two pairs of pictures are the same or one of the pictures from the pair was mirrored. We hoped to find that there were not differences. More precisely, that the confidence interval for the difference is so small, and the effect of the first experiment cannot be explained by any differences of the stimuli. Surprisingly, we found a difference in the reaction times but it was in the opposite direction. The light stimuli appeared to be harder for recognition that the heavy ones. Thus, the effect of the first experiment should be thought even higher.

One more interesting finding was that there was not an interaction between the angle of rotation and the weight of the stimuli. This was in congruence with the results, obtained by Flusberg et al. (2009). The authors suggest that it takes more time for the people to start rotating mentally the heavier objects but once people start, there is no matter the angle of rotation (Flusberg, Jenkins & Boroditsky, 2009). Additional theoretical suggestions and empirical evidences should light more this question.

6. Conclusion

A huge number of empirical evidences for the interaction between the mental and motor representations emerge during the last decades. The concept of embodiment combines a broad range of theoretical views. The theory of grounded cognition suggests that our physical experience with the world affects the way we think about it. The human's body is an everyday living tool and each single movement is recorded in the memory not just as a computational operation but as a complex knowledge which can be used on a later stage even in our imagination. People unconsciously implement their physical experience with the environment when they imagine doing things and that imposes a restriction in the fantasy. The grounded cognition leads people to search the easiest way of performing an imagery task, as they would do if performing it actually. People can change their existing belief about the arrangement of objects in space depending on the size of the objects and their movability. In an experiment, subjects preferably changed the position of small objects rather than the large objects and also relocated the easy to move objects faster than the hardly movable objects (Nejasmic, Bucher & Knauff, 2013).

Studying the embodied knowledge shifts the idea that the cognitive processes are not only abstract symbolic manipulations but they are grounded in the motoric and perceptual, even the emotional, experience (De Vega, Graesser, & Glenberg, 2008).

Shepard and Metzler (1971) found that people mentally rotate the representations of objects when solving problems. Those findings are of critical importance for the study of embodiment.

If the cognition is embodied then the question if things that are more difficult to physically manipulate are also hard to mentally manipulate (Flusberg & Boroditsky, 2011) is reasonable. In our experiment participants mentally rotated representations of an images of real objects, there were not drawings of body parts (Paesons, 1995) or angular figures (Shepard & Metzler, 1971) but there were photographs of actual objects used. Those were objects that we use in our daily life, or at least we have met. According to the evidence of motor imagery, that we elicit from the memory our previous or immediate motor experience when thinking of actions (Flusberg & Boroditsky, 2011), our results are interesting. It is possible that in our mental imagery we are influenced of the knowledge that we have about the world that we act in. If the only difference between mental and actual movements is the motor output, so maybe mental manipulation could be based on the knowledge about some properties of the environment around us and the objects that we have deal with as well as the motor experience is. We used stimulus of objects, some of which people could not manually manipulate. We suggest that in those cases some embodied cognition could be involved based on what we know. We would think and know of some object that it is very heavy and nobody could lift it. For instance one would probably mentally rotate and manipulate a representation of a truck slower than some light object based on his knowledge that the truck is very heavy and on the representation of how it would be to manipulate it. It would be an interesting initiative to investigate those ideas in more details in future.

Nevertheless that the topic may seem too specialized, it supports the embodied view to human cognition. In this way, the findings have not only theoretical merits, but can be of high interest for education planning. Studying the effects of the body on the mind contributes the education planning and has an increasing role in mathematics education and problem solving issues in high school, college and beyond. The physical activity seems to be helpful in developing different learning skills.

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