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DO NOVICES IN MECHANICS SHOW INHIBITION WHEN THEY CORRECT THEIR ERROR TO PROVIDE A SCIENTIFIC ANSWER?

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An extensive research literature in the field of science education reveals that students often hold misconceptions. In particular, physics seems to be a discipline for which the persistence of misconceptions is especially pronounced. Recent studies point to the idea that the brain mechanism of inhibition would play a role in overcoming those misconceptions and learning science. However, the cerebral mechanisms underlying error-correction for novice learners are not well known. Do novices in mechanics show inhibition when they correct their error and provide a scientific answer? To answer this question, sixteen novice participants took part in this study. The misconception "a heavier ball falls faster than a lighter ball" has been chosen since it is widespread and known to be very resistant. First, participants were asked to evaluate the correctness of three types of stimuli: non-scientific ones that did not follow Newton's laws of motion and were therefore in line with the studied misconception; scientific movies that followed Newton's laws of motion; and control stimuli. fMRI was used to acquire functional images during the task. They were then shown the correction key and were asked to evaluate the stimuli again. At pretest, all participants produced wrong answers and evaluated mostly non-scientific stimuli as correct and scientific videos as incorrect. As a result of being shown the correct answers, they corrected their errors and provided scientific answers. We expect to see a greater activity in brain regions associated with inhibition when comparing the posttest with the pretest. The underway analysis will allow us to present first results at this conference.

Keywords: misconceptions, error-correction, inhibition

INTRODUCTION

An extensive research literature in the field of science education reveals that students often hold misconceptions about various natural phenomena that are not consistent with scientific knowledge and therefore interfere with learning (diSessa, 2014). It is also well documented that these conceptions often persist even after students have received formal instruction in scientific conceptions (Wandersee et al., 1994) and are thus considered hard to change (diSessa, 2006). In particular, physics seems to be a discipline for which the persistence of misconceptions is especially pronounced. The misconception that "a heavier ball falls faster than a lighter ball" is known to be widespread among children and very resistant to teaching (Wandersee et al., 1994). How is it therefore possible to overcome this misconception in order to reason scientifically? It has been proposed that inhibitory control mechanisms would play a role in learning science. Indeed, some studies comparing novice and expert participants have shown that inhibition would be involved when experts in science answer correctly to questions involving a common misconception in chemistry (Nelson et al., 2007) electricity (Masson et al., 2014) and physics (Brault Foisy et al., 2015). However, the cerebral mechanisms underlying error-correction for novice learners are not well known. Do novices in mechanics show inhibition when they correct their error and provide a scientific answer?

METHOD

Participants

Sixteen male adults (*M* = 23.5 years old, *SD* = 2.8) participated in this study. Women were excluded from the study because of a possible inter-subject variability related to gender (Grabner et al., 2007). No participants reported abnormal neurological history and they were all right-handed (Good et al., 2001) and had normal or corrected-to-normal vision. To limit inter-subject variability due to differences in academic performance, participants were excluded from the study if they had an average university score considered atypical. All participants were humanities students in bachelor's-level programs who had never taken optional science classes, so they were regarded as having a mere basic science education.

Task and stimuli

The cognitive task involved three types of stimuli: non-scientific movies that did not follow Newton's laws of motion; scientific movies that followed Newton's laws of motion; and control stimuli for which the experts and novices were presumed to answer similarly because the studied misconception was not likely to be involved. Participants were asked to judge if the movies were scientifically correct or not. They responded by pressing a button on a response pad. The visual stimuli used in the task involved two balls of different sizes (big, medium, and small) and participants were told that the balls were made of lead. The larger ball was therefore considered to be significantly heavier than the smaller one, but both were heavy enough for air resistance to be negligible. The movies showed the balls falling at the same or different speeds. The non-scientific movies were consistent with the novices' conceptions, i.e., the heavier ball fell faster and hit the ground before the lighter ball. The scientific movies were consistent with the experts' conceptions; i.e., the balls fell at the same speed and reached the ground at the same time. The control movies showed the lighter ball falling faster and touching the ground before the heavier ball. For these control stimuli, both novices and experts were expected to answer that the situation was incorrect.

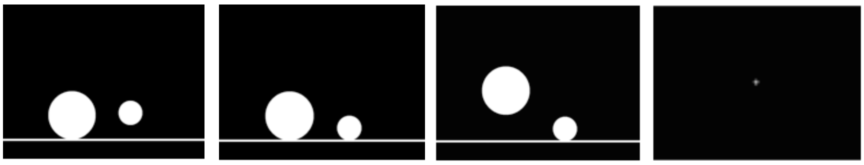

Figure 1. Types of stimuli used in the task.

After two series, the correction key was presented to the participants: the movies they needed to evaluate were presented to them again, this time along with the expected answer. For example, for the non-scientific movies showing the heavier ball falling faster than the lighter ball, the caption "incorrect" appeared on the screen. During the presentation of the correct responses, participants were only asked to look at the screen but they were not answering. Following the presentation, they were asked again to evaluate the accuracy of the same movies. The stimuli were presented the same way as they had been before participants were shown the correction key, i.e., randomly in two equivalent series (series 3 and 4).

Image acquisition and analysis

Functional images (T2*) were acquired during the four equivalent series with a Siemens 3.0 Tesla MAGNETOM Trio TIM and a 12-channel head coil. Each serie lasted about 7 minutes with a pause of about 3 minutes in between. Structural images (T1) were acquired while the participants were at rest. The accuracy rates were analyzed with SPSS using paired t-test to compare the participants' accuracy before and after the intervention. The fMRI data will be preprocessed and analyzed using SPM8 (Wellcome Department of Imaging Neuroscience, London, UK). Data analysis will be carried out using the general linear model. More precisely, data will be modeled for each trial using the canonical SPM hemodynamic response function. The six movement parameters will be entered in the model as regressors of no interest. A first-level analysis will be used to average the functional series of each participant. A second-level group analysis (random effect analysis, t-test) will be performed to obtain the contrasts of interest (i.e. posttest vs pretest).

RESULTS

At prestest, participants performed very poorly for both scientific ($M = 0.0094$ of 1, $SD = 0.0965$) and non-scientific ($M = 0.0438$ of 1, $SD = 0.205$) stimuli, but very well for control stimuli (M = 0.875 of 1, *SD* = 0.331). At posttest, they improved their response accuracy for both scientific (*M* = 0.925, *SD* = 0.264) and non-scientific (*M* = 0.806, *SD* = 0.396) stimuli, while maintaining very high accuracy for control stimuli (*M* = 0.884, *SD* = 0.320). Performance increases were very significant for both scientific ($t[319] = 56.592$, $p < .001$, $d = 4.610$) and non-scientific ($t[319] = 31.464$, $p < .001$, $d = 2.419$) stimuli, while no difference with pretest was observed for control stimuli ($t[319] = 0.390$, $p = .697$, $d = 0.029$). Regarding the neuroimaging results, we hypothesize that participants will show a significantly greater activity in prefrontal regions of the brain associated with cognitive control and inhibition, such as the ventrolateral prefrontal cortex and the dorsolateral prefrontal cortex, when answering at posttest compared to pretest. If this hypothesis is confirmed, showing the correct responses to novice learners would elicit a neural response representative of expertise in mechanics. An alternative hypothesis could however be that participants will engage more intensely brain regions associated with memory retrieval such as the left angular gyrus (Grabner et al., 2009) at posttest. According to this hypothesis, when novice participants correct their initial errors and answer scientifically, neural correlates subtending fact retrieval will be observed. If this hypothesis is confirmed, novices would thus not mobilize executive functions similar to those of mechanics experts when they correct their errors. Preliminary observations of the data point to this second hypothesis but further analysis will be necessary to confirm the results.

DISCUSSION AND CONCLUSION

In order to better inform the design of instructional strategies in science teaching, it becomes important to determine as a first step what happen to novice learners when they are presented with a scientific situation that contradicts their initial conception and lead them to correct their error. Possible educational implications of these results will be discussed in greater depth during the presentation.

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