Multimodality and learning: linking science to everyday activities

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Abstract

This paper focuses on the role of multimodal systems in education. The importance of using multiple modalities in communicating information while learning has been recently acknowledged by educationalists. Multimodal human-computer interaction for learning tasks could be an alternative path to pioneering effective computer aided learning. Multimodal technology could offer new opportunities to learn from everyday activities in the classroom. The act of moving the hand, for example, could lead to interesting conclusions about hand's displacement and its graphical representation. However, there are several challenges that multimodal technology faces: it is not only a matter of how and when the system will present information to the user, but also where the learner would need support (educational content), what activities would keep them engaged. The paper will report a study aimed to explore these issues empirically.

1 Introduction

A modality can be defined as a means to communicate information, i.e., a sensory channel via which information is passed from or to a person. Modalities can be used individually or in combination. Multimodality refers to the simultaneous or alternate use of more than one modalities to send and receive information. In a multimodal interaction someone may receive information by vision and respond by speech or movement. Human- human interaction, e.g. in a classroom, is basically multimodal: the interaction between visual, actional and linguistic communication can be employed in learning (Kress & Jewitt, 2001). It is argued that use of multiple modalities while learning engages learners' interest and facilitates the process of learning.

Human–computer interaction can be multimodal as well as unimodal. By multimodal human-computer interaction we mean interaction between human and computer that involves interaction devices supporting different response modalities, e.g. pointing and speaking, or supporting the use of at least two sensory modalities, e.g. vision and hearing, or a combination of these (Baber and Mellor 2001; Carbonell 2001). Multimodality could be contrasted to 'unimodality', which is based on the use of only one modality to sense and respond to information. An example of unimodal activity could be watching an animated presentation on a computer and responding only by pressing keys on the keyboard; in this example, the visual-spatial modality is used for both activities.

When technology can support the multimodal interaction in a learning activity, meaning construction can be facilitated. In a highly interactive environment new configurations can be tested by the learner who constructs and negotiates meaning with the aid of the system's feedback (Scaife M., 1996). The integration of different modalities gives the opportunity to configure real-life actions, such as hand movements. Representation of information to each modality is also an issue. If representations such as diagrams or graphs are *easily* produced by the learner, comprehension of the representing concepts is intimately facilitated (Scaife M., 1996). When visual representations are effectively coupled with movements, learners can relate representations to their sense and knowledge about their body and experience body syntonic learning (Papert, 1980). Thus, using movement as a means to record data, which is displayed in graphs and results in correction of the movement is considered as a multimodal learning experience. This paper describes a study that explores whether such an experience is beneficial when learning about kinematics graphs.

2 Learning about graphs

For the students to learn how to interpret a graph, the relation between the movement and the line of the graph is important. Seeing how the graph is plotted by their hand movement and being able to change it as they move about, gives them the ability to test their ideas and discard the problematic ones. When learning about kinematics, for example, pupils often ignore the abstract concept of the graph and think of the graph as a picture of motion, i.e. a line parallel to the time axis could be erroneously assumed to describe a horizontal movement and a line going upwards describes a vertical movement. By using a sensor on their hand to collect data for drawing a graph, the pupils can negotiate their understanding: they relate their physical movement to the appearance of the graph. Looking at the generated graph in real time can also provide 'graphical constraining', that is the real-time graph constrains the inferences that can be made about the underlying represented world (Stenning & Inder, 1995). Thus, the lines are interpreted as movement or lack of it instead of movements along different dimensions. Having a system to generate kinematics graphs from their own data, gives pupils a meaningful situation to consider: an authentic problem that refers to real life situations and which is thus worthwhile to think about.

However, as shown by a pilot study, there are technical difficulties that can arise from the initiation of such an innovative learning experience. Time delays in displaying the graph might weaken the link between the activity and the graph formation. The presentation of the graph also needs to be considered: very condensed graphs can be difficult to relate to the hand movement. An activity can also raise usability issues: a rapid activity does not give enough time to participants to realize how their movement affected the graph. Additionally, the educational focus needs to be related to the students' curriculum for it to be a valid classroom activity.

3 Main Study

The study explores the relation between learners' own hand movements and their graph formation and understanding.

The technology included a position measuring system that sends data to a software that displays the graph in real-time (Figure 1). The learner attaches the sensor to their hand and moves the hand about to see a distance-time graph.

The activity was initially open-ended: the learner could move their hand in any way they wanted. Later, they are asked to generate specific graphs so they had to find out how they should move their hand, aiming at strengthening the link between the activity and the graph. They could move their hand towards any direction but it had to be the same throughout the study.

The learning content was about distance-time graphs, which is an important issue in the science classroom for Key Stage 3 in UK and elsewhere. The pupils need to learn how to identify when the graph shows movement or lack of it; when there is movement, they need to understand its direction and to interpret the slope of a graph in terms of speed of the movement.

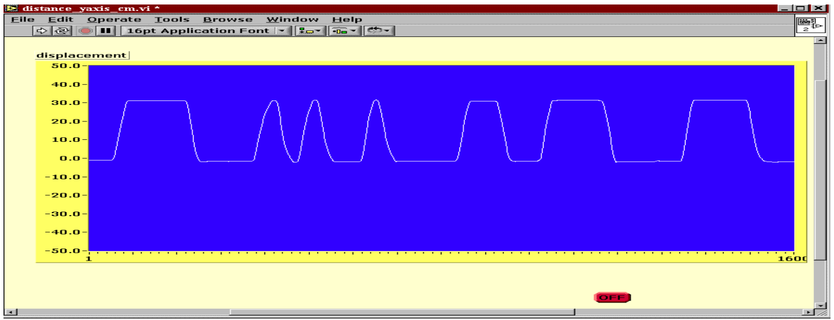

Figure 1: Screenshot of the display

3.1 Method

The study was conducted with 22 students in year 9 (14 years old) of a secondary school in Birmingham, UK. It was expected that the students would know little or nothing about the subject because they had not then been taught distance-time graphs. Students were assigned to the conditions on presentation to the experiment. In each session, there was one student in an empty classroom with the experimenter for about half an hour.

There were two conditions: students who formed graphs as they moved their hand (Doers) and students that thought about their hand movements in order to explain the graphs (Thinkers). The thinkers were also allowed to move their hands, but their movement did not generate a graph plot Both conditions had access to body syntonic learning: they had to imagine the graphs as expressions of their own movements. The experimental condition (Doers), however, had a reinforced experience. They had the chance to correct themselves as they saw the results of their movements on the visual display. It was expected that by relating graphs to hand movements and getting immediate corrective feedback from the display, learners would be more able to understand graphs and will do so more easily and with more interest than those in the control condition.

The feedback from the experimenter was kept to a minimum: the learners received feedback at the beginning of the teaching session where two very simple graphs were explained to them. This was necessary for the thinkers to continue the study. During the teaching session they had to interpret 4 graphs, of varying difficulty. A set of verbal protocols was used, to ensure that all students are given exactly the same instructions. For the teaching session the group was split into the 'Thinkers' and 'Doers'.
The 'Thinkers' were shown specific graphs and they could either say what they would do to generate them or move their hand accordingly. They discussed with the experimenter about the details of the graph, i.e. the name of each axis, the values it would have and what a negative value would mean. Subsequently, students were asked to write down what they said or did.

The 'Doers' had the tracker's sensor attached to their wrist with the aid of a sweatband. They moved their hand about freely to get familiar to the movement and the generation of the graph for approximately 3 minutes. Meanwhile, they discussed the details of the graph with the experimenter. The students tried afterwards to generate specific graphs. After they had caried out the task they wrote down their results.

The third part of the experiment involved the students answering questions in the form of a written test. They could not look back to the previous sheets. Finally, the pupils were asked to reflect on the experience and express their opinion about the study. They completed a short attitude survey, based on a 5 point Likert scale. In particular, they were asked whether they found the session interesting, if they liked it, if the liked watching their own data, how difficult were the questions and whether they felt that they understood the distance-time graphs at the end.

3.2 Results

The results discussed below are based on the sheets completed. The final test results of the two conditions were significantly different (Mann-Whitney test $z = -2.275$, $p<0.05$). Comparison of individual questions shows that ‘Doers’ were more able to describe the distance-time graph in terms of hand movements and they understood better the meaning of each line on the graph.

From the initial set of questions, it was apparent that none of the students know about distance-time graphs. There was no difference in what the students knew before the study between conditions. From what the students wrote next to the graphs of the teaching session, it appears that the ‘Doers’ were more able to describe correctly the graphs in terms of their hand movements.

When asked for their opinion about the study, ‘Doers’ liked it more than ‘Thinkers’ (Mann-Whitney test, $z=-2.181$, $p<0.05$) and found it more interesting (Mann-Whitney test, $z=-2.355$, $p<0.05$). Most of the students, in all conditions, indicated that they would like to watch their own data. All the participants responded that they understood ‘distance-time’ graphs.

3.3 Discussion

‘Doers’ performed better overall than thinkers. In particular, ‘Doers’ were more able not only to interpret correctly the graphs into general movement but also were able to translate correctly graphs into hand movements. All ‘Doers’ also mentioned a sensible direction in which the hand would move. This is in contrast to the ‘Thinkers’ who were less able to translate the movement into a sensible direction. A frequent response was that a straight line expresses movement across and a sloped line expresses a movement diagonally (picture-like effect).

Initially, most of the participants thought that they had to move their hand diagonally in order to draw a diagonal line on the graph. ‘Doers’ could overcome this problem because they could see that the effect on the graph was not the expected. They had the chance to self-correct themselves via the visual feedback and discover the correct movement. Thus, having access in graph generation resulted in solving common misconceptions: the system constrained their inferences about the underlying represented world.

It was also noticed that ‘Doers’ tended to have more standardized behaviour than ‘Thinkers’. The system and the task triggered their attention and they concentrated on their answers. They stayed focused on the task since they actively constructed knowledge through experimentation. During the study, they negotiated the meaning of the problem at hand and they discovered which concepts where applicable. They were dealing with a real-life situation which gave them an authentic problem which was related to themselves. Conversely, the participants in the control group paid attention to some of the tasks of the session but because of the lack of feedback, they got bored or distracted.

3.3.1 The learning experience: the system, the activity, the educational content

‘Doers’ were fascinated by the system. Moving their hand about and seeing its distance-time graph on the visual display was an engaging experience. The feedback came from the visual display as soon as they moved their hand and they could alter the pace of their movements to notice the changes on the graph. They were watching the display with interest and they were drawing conclusions about the effect of moving (or staying still) on the graph.

The activity they had to do was not specific. They could move towards any direction as long as they kept it the same throughout the study. They could try to move their hand differently, test new configurations and realise the changes on the graph by the system's feedback. Being able to change the graph as they moved about, they related the graph to their sense and knowledge about their body, thus having access to body syntonic learning.

The study was successful in reaching its educational aims. The main aim was gained by both conditions: they realised that a straight line on a distance-time graph shows no movement and the diagonal line shows movement. However, the ability to interpret the lines of a graph in terms of hand movements with correct direction was much more pronounced for 'Doers'. The third aim of the study was focusing on the slope of the lines: the steeper the line the faster the movement. Students from both conditions were able to answer the relative question correctly. This was expected because it was explicitly explained by the experimenter.

3.4 Conclusion

The study described above showed that introducing multimodal interaction in a learning activity makes learning more interesting and effective: it facilitated students' understanding and engagement. It related students' own hand movement to graph formation and interpretation: instead of focusing on any object of the environment it was thought that the use of their body would interest them more and would trigger them for a better understanding of the graph and what it shows. The integration of different modalities, i.e. kinaesthetic and visual, in a learning activity gives the opportunity to test real-life actions and receive feedback from the system. Visual representations that are effectively coupled with movements, facilitated comprehension of kinematics graphs and related science to their body. Thus, using movement as a means to record data, which is displayed in graphs and results in correction of the movement is considered as a beneficial multimodal learning experience.

Multimodal systems for educational purposes are introducing a new phase in computer aided learning: the aim to develop systems that support learners in ways that enrich the whole learning experience by giving access to information that was previously hard to obtain and visualise.

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