Epistemic action: A measure for cognitive support in Tangible User Interfaces?

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Introduction

In the field of Human-Computer Interaction the usability of a program or tool is often measured in terms of efficiency, effectiveness, and satisfaction [1]. Recently, in the field of Tangible User Interfaces (TUIs) an additional measure for the quality of tangible tools was introduced: epistemic action. Kirsh and Maglio [2] distinguish between 'epistemic' and 'pragmatic' actions. An epistemic action is an action whereby users change their environment to search for a solution or strategy to perform a certain task. A pragmatic action is strictly the action needed to actually perform this task. Kirsh and Maglio illustrate this with the example of how players of the game, Tetris, rapidly rotate the falling bricks instead of mentally determining the correct position for a brick and then rotating it to the correct position. Players use epistemic actions to modify the environment which helps them to determine the correct position. They can do this faster than the corresponding mental rotations. It might be easier to physically modify the external world and then interpret it rather than compute and interpret a new state internally. It has been suggested that epistemic action is a relevant concept when researching computer interfaces that involve physical objects such as TUIs [3]. Sharlin et al. [4] suggest that support for epistemic actions is an important factor in the success of a TUI. In this paper we look at three different spatial planning tools and aim to relate the traditional measures of efficiency, effectiveness, and satisfaction with the number of epistemic actions to determine whether this last measure can additionally be a useful measure of quality for TUIs.

Epistemic action and TUIs

According to Fitzmaurice [5] epistemic actions can support a user's cognition by:

- Reducing the memory involved in mental computation
- Reducing the number of steps in mental computation
- Reducing the probability of error of mental computation

TUIs offering tangible objects that can be physically manipulated may offer more cognitive support than interfaces without these objects because they support epistemic actions.

In order to study epistemic action as a quality measure we designed a spatial planning task [6]. The task was to find the unique of many alternative blocks on which to place a laser source in order to hit a nearby target with its light beam. The beam should be as close as possible to the centre of the target. Nine square blocks with different heights formed a three-by-three matrix. The laser source could be placed and slightly adjusted on any of the nine blocks.

We chose three different tools to fulfil this task, each offering a different degree of physical interaction:

1. No physical interaction: Modeller, a CAD tool with virtual tools and views [7].
2. Some physical interaction: BUILD-IT, which employs a virtual modelling of the blocks, target, and laser source. The participants use one physical brick to manipulate the virtual laser source.
3. Only physical interaction: PhysicalBlocks, consisting of nine metal blocks, a standard laser source, and a target consisting of a metal pin attached to a metal flag. The participant can adjust the height of the metal flag, the target position, and the block positions.

Experiment and results

In an in-between-subject experiment [8] we measured efficiency (trial time), effectiveness (percentage of correct trials), satisfaction (questionnaire), and epistemic action (average number of tested blocks in a trial). Each tool was assigned to ten participants who each had to perform ten task variations. PhysicalBlocks yielded the lowest trial time, the highest percentage of correct trials and the highest user satisfaction. Modeller yielded the highest trial time, lowest percentage of correct trials, and the lowest user satisfaction. BUILD-IT yielded results in the middle of the other two for all measures. These results can be related to how much physical interaction each tool offers. As for epistemic action, we saw a result that was not related to any of the traditional usability measures. The number of tested blocks in a trial was lowest for PhysicalBlocks, but highest for BUILD-IT and in the middle for Modeller. Epistemic action measured by the number of blocks tested was not directly related to the level of physical interaction offered by the tool. The tool that offered most physical interaction was, indeed, the tool with the lowest number of blocks tested in a trial.

Discussion and conclusions

Our experiment makes us rethink epistemic action as a simple linear measure for the successfulness of a TUI. A primary observation is that PhysicalBlocks offers users the possibility to change the position of their head to determine the correct block. This will not result in a countable epistemic action expressed by testing a block. Furthermore, it is also possible that PhysicalBlocks offers so much support in the physical world that epistemic actions to modify the world are not even necessary. Since epistemic action may take different forms, using it as a measure for TUI success should be considered with care. In future work, we firstly need to determine more specifically what should be considered an epistemic action. Secondly, it is possible that increased possibilities for physical interaction decrease the need for modifications in the environment in order to find a solution or strategy. This might result in a lower number of epistemic actions for tools that provide more cognitive support.

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