Memory Decay Problems in a Level-Repetition Switch Task Model

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Introduction

A classical example of a switch task is a task in which both a digit and a letter are presented to subjects, and, depending on the condition, where they are asked either if the letter is a vowel or a consonant, or if the digit is odd or even (e.g., see Rogers & Monsell, 1995). This can be done in the so-called alternating runs design, where the task is alternated in blocks of for instance four trials. Every first trial of a block is called a switch trial, and is compared to the other trials within a block. Performance on these switch trials is usually significantly slower and more error-prone than on the non-switch trials (e.g., Monsell, 2003).

One of the hypotheses why this phenomenon occurs is that subjects do not have enough time to prepare for the new task. However, if one increases the time between trials, only part of the switch cost disappears (Rogers & Monsell, 1995; Altmann, 2004). Thus it is not possible to completely prepare for a new task. Even when the subjects are cued and when they may decide themselves when the next trial starts, a residual switch cost remains.

A subset of the switch paradigm is the level-repetition task (Hübner, 2000). In this task, the stimulus level on which the response has to be based is changed. In one of the conditions, subjects have to pay attention to the global level of the stimulus, in the other condition to the local level. For example, a stimulus can be a large letter made up of small ones, where the task is to identify the letter (Hübner, 2000). These conditions can be presented in the alternating runs design.

Besides the same switch effects as previously described, an additional task-level effect is observed. The identification of the local stimuli takes longer than of the global stimuli. This is in accordance with the global precedence theory (Navon, 1977), which states that stimuli-levels are processed sequentially: global features become available before local features.

Experiment

We conducted a level-repetition task, but instead of the compound letters described above we used geometrical figures (after Huizinga et al., accepted). A stimulus was either a rectangle or a square, consisting of either small rectangles or small squares. Participants had to respond to either the global or the local level.

The procedure was as follows: a trial started with a cue, saying either 'local' or 'global', to tell the participants which level they should attend. This cue remained on the screen for 500 ms, after which it was replaced by the stimulus. Participants had a maximum of 3500 ms to respond. The intertrial time was 1000 ms, during which only a fixation cross was shown.

The experiment consisted of three practice blocks: a local and a global block of 30 trials each, and a mixed block of 100 trials. Afterwards there were three experimental blocks: a local and a global block of 50 trials each and a mixed block of 160 trials. The order of the local and global blocks was counterbalanced over participants.

Prior to the experiment informed consent was obtained from the participants. They had all normal or corrected-to-normal visual acuity. The mean age of the 14 participants was 23.9, 7 of them were female.

The significant results are shown in Table 1. Besides the clearly visible switch effect, it can be seen that the trials in the non-switch blocks are performed faster than the trials in the mixed block. The task-level effect is obvious as well; global trials take less time than local trials.

Model

ACT-R was used to model this behavior. The model begins the task by perceiving the cue and retrieving the appropriate goal. As this is easily done within the 500 ms cue-time, this cannot be the source of any switch cost (but see Sohn & Anderson, 2001).

The next step comes when the stimulus appears. The visual system perceives the stimulus, and starts spreading activation to two out of four chunks representing high-level visual features: one chunk for large squares, one for large rectangles and two chunks representing the small squares and rectangles. Because it takes longer to perceive local figures (Navon, 1977), the time course of the activation of the stimuli is split up for the local and global level. This is done by letting the activation gradually increase, where the local level starts later than the global level.

Table 1: Mean Reaction Times.

Single Task Blocks		Mixed Block	
Global	Local	Switch	Non-Switch
376	392	489	430

The activation is not only spread to the 'correct' chunk. For example, if the visual system 'sees' a global square, it will spread a considerable amount of activation to the global square chunk, but a little activation to the global rectangle and the local square chunks as well. The local rectangle chunk does not receive any activation.

These visual chunks start in their turn to influence the stimulus-response chunks. This is not modeled in standard ACT-R, but in the RACE model of Van Maanen & Van Rijn (2006). Because the activation of the visual chunks constantly changes, and the local information comes available later than the global information, it is not possible to model this with the standard ACT-R equations, because these equations only sample at one moment in time.

Opposed to this, RACE calculates the levels of activation over an extended period of time. Every time step (5 ms) positive and negative evidence is sampled. Positive evidence comes from chunks of a different type, and negative evidence from chunks of the same type. The amount of this excitation or inhibition is based on the activation of the source chunks and the association between the chunks. The competition between the chunks ends when the base-level plus the sampled evidence of one of them reaches a threshold. This chunk is then retrieved with a retrieval latency of the time it took to execute the RACE model.

This means the following for our model. First of all, the retrieved goal chunk spreads activation to two of the four stimulus-response mappings. When the stimulus appears, the visual chunks start spreading their activation. At the same time, the mapping chunks are inhibiting each other.

If a chunk recently has been retrieved, its base-level activation will be higher. Because the activation of the chunks determines the level of inhibition, this means that chunks which have just been retrieved are spreading more inhibition than the other chunks, which influences the retrieval latency. Due to decay the 'correct' chunks on a switch trial will have a lower base-level activation than the other chunks, therefore the task will take longer and be more error-prone than on a normal, non-switch trial.

Results & Conclusion

Our basic model shows the expected behavior: switch trials take longer to perform than non-switch trials. However, the difference in reaction time is not as large as in human subjects, it is about 20 ms opposed to the 59 in humans. The task-level effect is accounted for, but there is no overall difference between the single task blocks and the mixed block. These findings can mean two things: either our model or an assumption of ACT-R is incorrect. We will argue for the latter.

As our model does show the basic effects, it seems that our assumptions are correct. The underlying factor of our model is base-level decay, however, the problem is that the base-level of chunks which are not important for the task at hand do not decay fast enough. A simple solution would be to increase the decay parameter, were it not that this parameter is as good as fixed at 0.5 in ACT-R. Moreover, if we change this parameter to for instance 0.9 this affects all chunks too strongly, and does therefore not give rise to a larger switch cost.

Letting the model learn the associations seems to be a solution for the fact that the model does not show a difference in reaction time between the single task and the switch task blocks. The problem is that associations do not decay, and keep increasing during all the blocks. This gives an opposite effect, as the trials in the mixed block are performed faster. Besides, this solution does not increase the switch cost.

A different way to solve the problem is to increase the intertrial time, which will make sure that the base-level activation of the chunks has more time to decay. This accounts for a difference between the mixed block and the other two blocks: because in the mixed block the chunks are less often retrieved, the base-level is lower and the average time to retrieve a chunk is higher than in the local and global blocks. As this does not give a difference within the mixed block, another change had to be made: the length of runs of the same trials was changed to 16 instead of 4 trials. Now the two chunks which are not task-relevant have time to decay, and a switch cost of 60 ms is found.

The obvious problem is that we now have a good fitting model, but with a different experimental setup from our initial experiment. Assuming a correct model, and having depleted possible ACT-R based mechanisms for explaining this behavior, the current approach to decay seems problematic in this type of task.

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