Stair- and Wave-like Development on the Balance Scale Task

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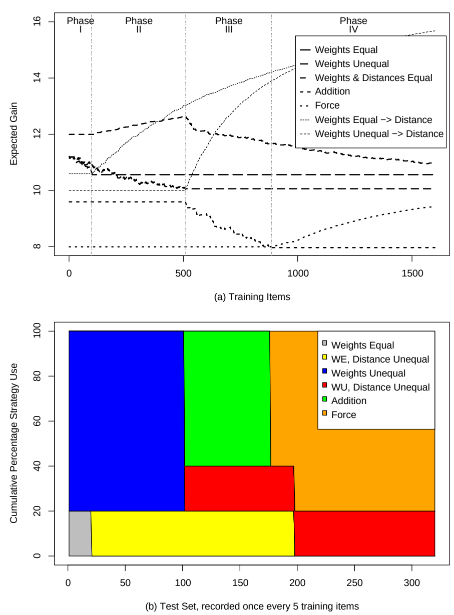
1 A Model of the Balance Scale Task

In our ACT-R model of the balance scale task, each path through the decision tree-like "Rules" as identified by Siegler (1978) is a separate production rule. Each rule is given an initial expected gain (EG) based on its complexity. During presentation of balance scale problems to the model, the EGs are adjusted by standard learning mechanisms. The training set contains a higher proportion of items for which weight determines the correct answer than of items for which another property determines the correct answer. As can be seen in Figure 1(a), the model proceeds through all four phases in the order as observed in human subjects. After each 5 training items, the strategies at that moment in use were recorded. Figure 1(b) shows that each transition to a new strategy is "stair-like", that is, abrupt and without reversion to a previous strategy.

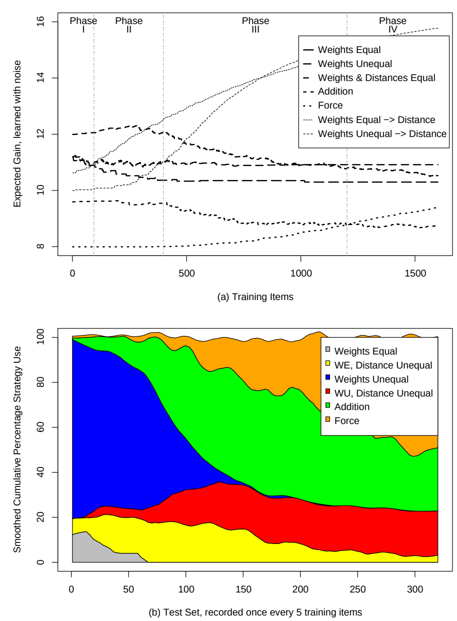
Figure 1: *Plot of expected gain of main production rules and plot of proportion strategy use.*



2 Wave-Like Transitions

Although the previously presented model fits the original theories about development, new insights predict a more wave-like transition from one phase to another. That is, at a particular time, one set of strategies is most dominant. However, the dominance of this set is adjusted by development and experience, gradually causing a new set to become dominant. The original model, but with EG noise, was presented the same learning set. Figure 2(a) shows that rules are being used before and after being dominant. This is reflected in the changes in EG for rules outside their "Phase". Figure 2(b) also shows that each strategy has its periods of "rise and fall", characteristic of wave-like transitions. Still, analyses of the data produced by the model show that it adheres to the rule-like behavior as found in human subjects.

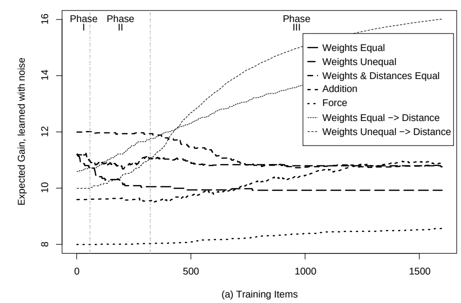
Figure 2: *Plot of expected gain of main production rules and smoothed plot of proportion strategy use, both based on runs with expected gain noise at 0.5*



3 Bias in Training Set

Although the model fits human data quite well, it is dependent on a training set in which more problems are present for which the weight property determines the correct answer. Figure 3 shows the changes in EG if the model is presented random problems, that is, problems from an unbiased learning set. Because the proportion of problems that can only be solved correctly with the "Force" rule is very small, the rule that determines an answer based on the product of weight and distance never becomes dominant. This is in accordance with the observation that most human subjects do not use this rule as dominant rule without explicit instruction.

Figure 3: *Plot of expected gain of main production rules, based on an unbiased learning set.*



4 Conclusions

- An ACT-R model consisting of simple rules is capable of showing stair-like development on the balance scale task by means of adjusting the expected gains of the production rules.
- Adding expected gain noise to this model increases the fit with human subjects by showing wave-like transitions while still adhering to rule-like behavior.
- The most advanced rule does not become dominant if an unbiased learning set is used. Thus, other influences than mere development and experience are necessary to master this rule, for example, explicit instruction.