Is Explicit Information Important for Performance in Dynamic Systems?

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In order to gain some insight in how to assist understanding and performance in dynamic systems, participants were asked to interact with a predator-prey system on a personal computer. Their task was to achieve equilibrium by controlling the size of the predator population. Results were presented in line graphs in all three conditions. In one condition pictures illustrating the population sizes was added, intended to make this information more explicit. In a second condition pictures illustrated the prevailing conditions in the system, to explicitly suggest conclusions to be drawn and actions to be taken. Although this was expected to facilitate performance, the results revealed an equally low performance in all groups. The overall success rate was 33%. This could be explained either as failure in interpreting the line graphs and/or the pictures not being explicit enough to assist deduction. Further research is needed to settle which was the case.

Keywords: understanding, control, explicit information, systems thinking, reasoning aids, task performance

Introduction

People frequently misinterpret the behavior of dynamic systems (Senge, 1990). Not even the simpler building blocks of dynamic systems are well understood (Sweeney & Sterman, 2000). What thinking is lacking? How could understanding and performance be enhanced?

Analysis of participants' problem solving processes when trying to establish equilibrium in an ecological system, suggests lack of the "indirect" thinking needed for control to be a major suspect of causing the low performance obtained (Jensen & Brehmer, submitted).

The ecological system was a simple predator-prey system described by the Lotka-Volterra equations (Berryman, 1998; Boyce & DiPrima, 1997, pp. 504-505; see also Richardson, 1991, pp. 36-38 for a system dynamic view). A predator-prey task used by Dörner and Preußler (1990; Dörner, 1996, pp. 144-152), served as a source of inspiration. Participants were informed of the parameters describing the system: the per-capita rate of growth of the prey population in the absence of prey, the consumption rate of the predators, the constant of conversion of prey into predator offspring, and the per-capita mortality rate of predators in absence of prey. The system was simulated on a personal computer and population sizes were the same at the start of each trial. A trial lasted 30 simulated years. The task was to find the population sizes where the system reached equilibrium. The participants were allowed to decide on the size of the predator population at the beginning of each simulated year. The prey population could only be influenced by means of the predator population. The result, population growth and/or decline, was presented in two line graphs, one for each population. An unlimited number of trials were permitted (Jensen & Brehmer, submitted).

The ecological system fulfils the minimum requirement for a closed system. It contains two variables and two causal relations, which was proposed by Doyle and Ford (1998, p. 18) to be the lower bound criterion for a dynamic system. We wanted the simplest conceivable dynamic system, describing processes familiar to most people. Thus, in the system rabbits produced baby rabbits, got caught and were eaten by foxes. Foxes produced puppies and died from disease or old age. We assumed that our subjects would understand these processes without any trouble.

Contrary to the task used by Dörner and Preußler (1990), two subtasks had to be achieved in order to reach the solution. One was to find out how to control the prey population by means of the predator population, which was also the task in the Dörner and Preußler (1990) study. The other one was to realize how the predator population could be controlled by means of the prey population, when the prey could only be affected through the predators. According to Senge (1990), the essence of systems thinking (understanding of dynamic systems) lies in "seeing interrelationships rather than linear cause-effect chains, and seeing processes of change rather than snapshots" (p. 73). To simply adjust the predator population to achieve control of the prey requires no more than linear cause and effect considerations. To establish equilibrium, an understanding is needed that how the predators affect the prey in turn affects the predators themselves by causing them to starve or prosper. Therefore the requirement to establish equilibrium was important, since this investigation focused on systems thinking skills. The task was also one of interacting with a dynamic process, rather than a one shot static decision problem.

The first subtask is one of exerting direct control, a task which people are fairly good at (Crossman & Coke, 1974; Moray, Lootsteen & Pajak, 1986). Most participants accomplished that part, but the second subtask proved to be more of an obstacle (Jensen & Brehmer, submitted).

Jensen and Brehmer (submitted) claimed that the rabbits-and-foxes task is similar to Wason's (1966, 1968) selection task. In the selection task the participants are given a conditional rule of the form "*if p then q*". One example used is the rule "*if a card has a vowel (p) on one side, then it has an even number (q) on the other side*" (Wason, 1966). The subjects are shown four cards with a vowel (*p*), a consonant (*not-p*), an even number (*q*), and an odd number (*not-q*), respectively, on the sides facing the subject. The subject is asked which card(s), if any, need to be turned in order to see whether the rule is followed or violated.

The rules "*if the rabbits increase then add more foxes*" and "*if the rabbits decrease then remove foxes*" have the same logical form as "*if p then q*". The task in the Jensen and Brehmer (submitted) study was not to investigate the truth of the expressions, but to act according to the rules. As described earlier, the subtask to use the foxes to control the rabbit population is fairly unproblematic, but to control the fox population by means of the rabbit population is a lot more difficult.

In the rabbits-and-foxes-task (Jensen & Brehmer, submitted), the participants are denied direct access to the rabbit population. If, for example, the fox population increases during a simulated year, a reduction of the rabbit population is required. The births of new foxes depend on the amount of rabbits eaten, which in turn depends on the amount of rabbits available. To reduce the rabbit population an increase in fox population is necessary. The rules "*if the foxes decrease then remove foxes*" and "*if the foxes increase then add more foxes*" surely defy any logic, but nevertheless describe the correct actions to take. A two-step indirect thinking chain is required to reach an adequate strategy. First one needs to understand that when the foxes increase, for instance, it is because they have too much food. Second one has to picture that a reduction in food quantity demands more foxes eating rabbits. The fox population is indirectly controlled through the rabbit population by means of the fox population itself. When the rabbit population has been made smaller, it is time to turn back to the first subtask. The foxes are adjusted to keep the rabbits at this new level and then the behavior of the fox population is again observed.

The correct solution to the selection task is to check both the *p*- and the *not*-*q*-card (the vowel and the odd number). Typically more than 90% of the participants fail to choose the false consequent (*not-q*) card to draw a modens tollens conclusion (Evans & Handley, 1999; Wason, 1968). For the conditional "*if p then q*", the following reasoning is required. If it is not *q* then it cannot be *p* on the other side, because that would falsify the rule. Therefore, it has to be *not-p* on the backside of the card.

Evans and Handley (1999) identified two potential threats to a successful solution of conditional inference tasks, of which the selection task is one. First, a premise may be disregarded as irrelevant. This frequently happens when implicit negations are used. If the rule is "*if the letter is D then the number is 4*", cards with explicit negations such as *not-D* or *not-4* are more frequently considered than cards with implicit negations such as *F* or *7*. This is called *the implicit negations hurdle*.

There are some indications that unsuccessful subjects ignore the fox graph or focus solely on that graph trying to obtain a "straight line". Perhaps they fail to grasp the message provided by the line graphs. The information may be implicit in a way similar to F and 7 in the selection task example. To test this hypothesis, pictures illustrating the population sizes were added to the graph presentation. Below the rabbit graph, pictures of small rabbits were presented, mimicking the rabbit population size described by the graph. A large rabbit population was represented by a square crowded by rabbits, and one lonely rabbit in the square represented a small rabbit population. There were some levels in between these extremes too. Increases and decreases were clearly illustrated. (For details, see the method section.) Below the fox graph were similar squares, but with fox figures instead of rabbits.

In a truth table evaluation task, participants were given a conditional rule together with all four logical combinations of minor premise and putative conclusion pertaining to the rule. The participants had to judge explicitly whether each case conformed to the rule, contradicted it or were irrelevant. Performance was better with explicit negatives than with implicit negatives. With the selection task, making negations explicit resulted in them being more frequently considered, but it did not result in better performance (Evans, Clibbens & Rood, 1996).

A modens tollens inference whose conclusion is affirmative, such as "*if not p then q*", would require the following reasoning. If it is not q then it cannot be not-p on the other side. **Not not**-p equals p. Therefore it has to be p on the opposite side. An additional step, the double negation not not-p equals p, has to be performed. Failure to do so was identified by Evans and Handley (1999) as *the double negation hurdle*.

A double negation effect was found on an evaluation task, where the content of both sides of the cards were given explicitly to be judged relevant or irrelevant for the rule to be true. The effect was more pronounced when explicit negatives were used. On a production task, where the task was to tell what must be hidden on the other side of the card for the rule to be true or if no conclusion is possible, no double negation effect was found. This task is similar to the standard selection task (Evans & Handley, 1999).

Simply presenting the graph information in pictorial form may not be sufficient to facilitate performance on the rabbits-and-foxes-task, just as using explicit negatives is not enough to elevate performance on the selection task. In the production task reasoners have to mentally construct what is explicitly given in the evaluation task. Tasks similar to the selection task probably fail to produce double negations effects because people never get far enough in their thinking to have the opportunity to fail at that hurdle. As with implicit negatives it appears to be a difficulty in mentally making explicit information given implicitly. Both the selection task and the rabbits-and-foxes-task pose such demands. What if efforts are made to make relevant information explicit in the rabbits-and-foxes task in a way similar to the evaluation task used by Evans and Handley (1999)? What in the rabbit-and-foxes task would correspond to presenting all possible card combinations in the selection task? Pictures integrating information about the rabbit population and the fox population suggesting consequences of the prevailing situation might fulfill a similar purpose. To test the effectiveness of such information to enhance performance on the rabbit-and-foxes task, pictures were constructed to describe the actual situation. These were used to supplement the graph presentation. Five pictures were created representing each of the four quadrants in the matrix below together with the intersection - the equilibrium (figure 1).

	Foxes	
Rabbits	Too few (< 50)	Too many (> 50)
Too few (< 900)		
Too many (> 900)		

Just right

Figure1.

When the rabbits are less then 900 there is too little food for the foxes. The foxes are starving and there are less foxes born than dying. There may be many or few foxes. Two different pictures illustrate each situation, but the conclusion following is the same in both cases. That is, a larger rabbit population is needed because the foxes are starving. A picture displaying a large horde of starving foxes with sparse rabbits hiding in the bushes was used to hint that a smaller fox population would be more suitable. In the case with only few foxes, starving foxes was intended to indicate that even if the rabbit population was growing it should be allowed to increase somewhat more.

When the rabbits are more than 900 and the foxes are less than 50, there is a foxes' paradise. They have plenty of food and produce a large amount of offspring. More foxes are born than dying, but until the fox population reaches 50 the rabbit population keeps growing too. A picture intended to indicate that the foxes had too god a time and were too few to keep the rabbits under control was used to suggest a larger fox population.

When there are more than 900 rabbits and more than 50 foxes, there continues to be enough food for the foxes to keep them well fed and increasing. The foxes, however, are consuming a diminishing food resource. Since they are abundant in numbers, they are eating more rabbits than are reproduced. This was the most difficult situation to illustrate. The rabbits are still too many. The decrease is necessary. A reduction of the rabbit population requires a fox population larger than 50. When the reduction is achieved, the fox population should be cut down to 50. A picture of non-starving foxes consuming stored rabbit resources was used to illustrate this situation.

Finally, to illustrate the equilibrium situation there was a picture with rabbits and foxes living in harmony (see the method section).

Method

Subjects

Participants were 24 undergraduate psychology students, 12 male and 12 female. Their mean age was 24 years, ranging from 19 to 42 years. Participation was voluntary and unpaid. The only reward received by the participants was a chocolate bar when the session was completed.

Task interface

The task with its graphical interface was developed using Borland C++Builder™ (2000, Version 5.0). The task was run on a personal computer (PC). The interface consisted of two line graphs, one for the rabbit population and one for the fox population (figure 2). In both graphs, the abscissa presented the years passing in the simulation, running from zero (start) to 30 years (end of trial). In the graph to the left on the screen, the ordinate presented the number of existing rabbits (ranging from 0 to 5000). The graph to the right presented the number of existing foxes (ranging from 0 to 250). The actual population sizes were presented numerically in the upper right corner in their respective graphs. Initial population sizes were 500 rabbits and 30 foxes.

Each trial lasted 30 years. The task for the subjects was to make the system reach its equilibrium state within 30 years. This would lead to horizontal lines in both graphs, after a couple of years to adjust the populations to their appropriate sizes.

Close to the fox graph, there was an editing box for changing the actual number of foxes to the number desired. When the participants were satisfied, they clicked a step button close to the editing box. This made a year pass in the simulation. If all rabbits were extinguished or the rabbit population exceeded 5000, the game was over and a new trial began.

Equilibrium was reached when the fox population remained constant at 50, which was the only level at which it would ever remain constant. A rabbit population *close to* 900 was necessary to achieve this. It did not have to be *exactly* 900. That would have been really difficult for the participants to achieve. When the rabbit population was approximately 900 and the fox population remained constant at 50, the rabbit population successively approached and eventually reached 900, where it remained.

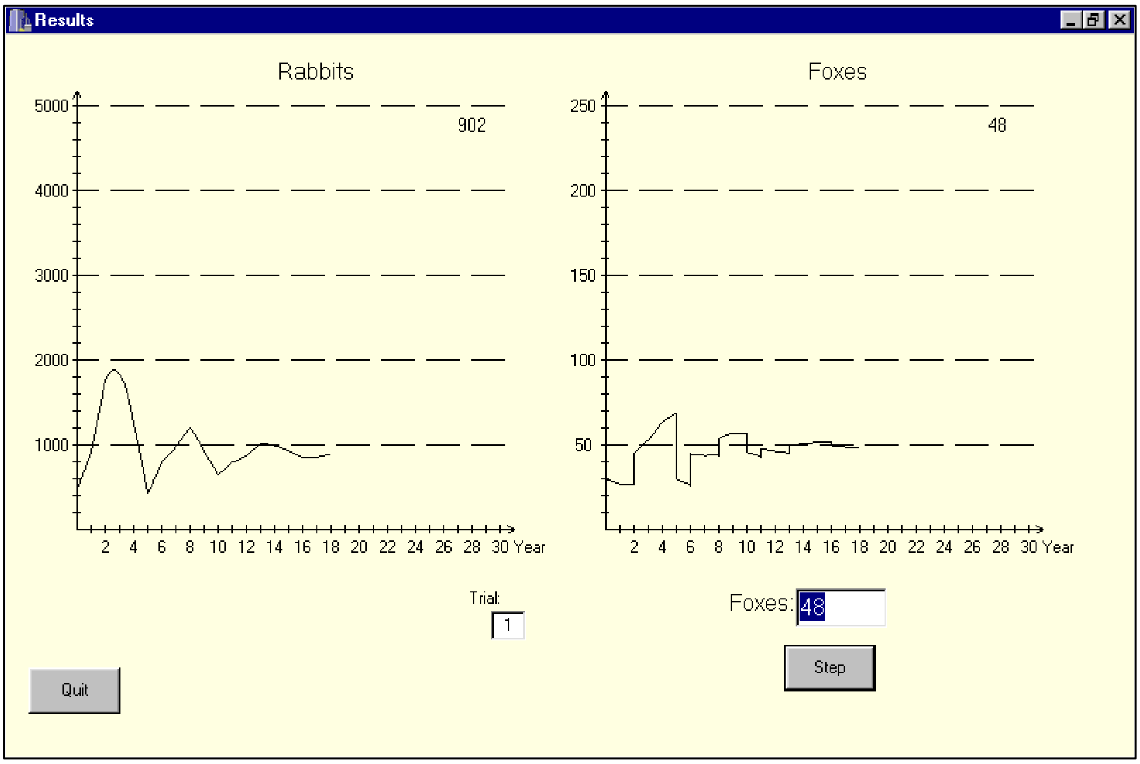


Figure 2. The task interface in the control condition.

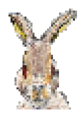
<u>Pictorial information</u>

Pictorial information was presented in the area below the line graphs. The editing box and the step button were placed above the fox graph in these conditions.

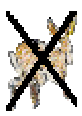
The first experimental condition

Pictures made up of small rabbit and fox figures represented the population sixes. Below the rabbit graph were presented squares with rabbit figures.

Existing rabbits: One (1) figure in the square represented 1- 400 rabbits, 3 figures 401-800 rabbits, 5: 801-1100 rabbits, 7: 1101-2000 rabbits, 9: 2001-3000 rabbits, 11: 3001-4000 rabbits, and 15: 4001-5000 rabbits.



New rabbits: These figures were used as the existing rabbits figures to represent a growth in the rabbit population during the immediate passed year.



Rabbits gone: These figures were used to represent a decline in the rabbit population during the immediate passed year.

Sometimes a series of squares was presented. When trends reversed during a year, it might look like figure 3:

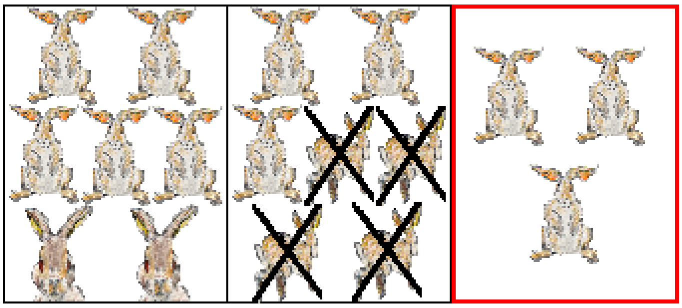


Figure 3.

In figure 3 the rabbits were 1000 at the beginning of the year. The rabbit population first increased to 1500, then the fox population grew large enough to cause a diminishing rabbit population. During the remainder of the year, the rabbit population shrunk to 700. The read frame of the right-hand square indicates the situation at present.

If there in stead were a steady increase from 1000 to 1500 rabbits, only the first square would have been presented within a red frame. Thus, the full figure rabbits represent the amount of rabbits at the start of the year, the rabbit heads the increase in rabbits during the year, and together they represent the number of rabbits by the end of the year.

Had there only been a decrease from 1500 to 700 rabbits, the last two squares would have been presented, with the right-hand square framed red. The total number of rabbit figures, the full figure rabbits and the crossed-over rabbits, represent the amount of rabbits at the beginning of the year. The crossed-over rabbits represent the decrease in rabbits during the year, and the full figure rabbits represent the remaining number of rabbits by the end of the year. In a "result" square, the full figure rabbits were presented again. This was done to give a clear picture of how many rabbits that actually remained.

Below the fox graph were similar squares containing fox figures.

Existing foxes: One (1) figure in the square represented 1- 20 foxes, 3 figures 21-40 foxes, 5: 41-60 foxes, 7: 61-100 foxes, 9: 101-150 foxes, 11: 151-200 foxes, and 15: 201-250 foxes

New foxes: Used in the same way as the corresponding rabbit figures.

Foxes gone: Used in the same way as the corresponding rabbit figures.

Using these figures solely would haven given only a rough idea of the changes taking place within the system. The following figures were added to illustrate smaller changes.

A smaller increase in the population.

A smaller decrease in the population.

The left square in figure 4 below illustrates a rabbit population growing from, for example, 500 to 650. It is an increase, but the population remains within the 401-800 range. The square to the right shows a fox population growing from 50 to 55.

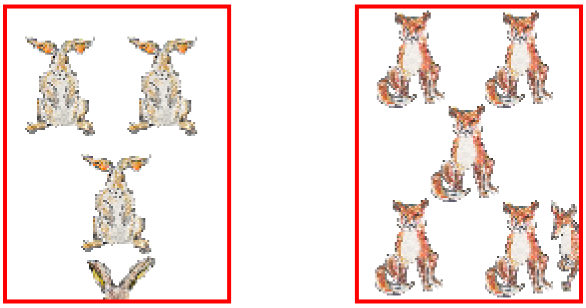


Figure 4.

A rabbit population decreasing from 1400 to 1200 would result in the square in figure 5.

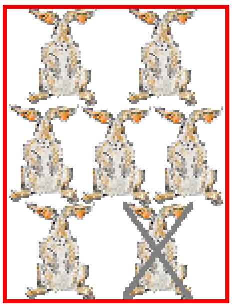


Figure 5.

The second experimental condition

Pictures describing the prevailing situation for the rabbits and foxes were presented below the graphs. The following five pictures were used (figure 6).

Rabbits < 900; Foxes < 50

There are few foxes.
There are also few rabbits, leaving the foxes with scarce food resources and low fertility.

Figure 6a. Pictures used in the second experimental condition.

Rabbits > 900; Foxes < 50

There are an abundance of rabbits, producing even more rabbits.
The existing foxes are stuffed with rabbits and produces large clutches of puppies.

Rabbits > 900; Foxes > 50

There are many foxes.
They have enough food to eat, but they are consuming diminishing resources.
The rabbit population is decreasing, but the foxes are not starving yet.

Rabbits < 900; Foxes > 50

There are many foxes.
There are few rabbits.
The foxes are starving and their reproduction rate is low.

Rabbits = 900; Foxes = 50

Equilibrium is reached!
The foxes have enough to eat to reproduce themselves at the same rate as they die off.
There are enough rabbits to allow them to reproduce at the same rate they are consumed by the foxes.

Figure 6b. Pictures used in the second experimental condition.

The pictures were presented in pairs. The picture to the left, with a thin black border, described the situation at the beginning of the year. The picture to the right on the screen, with a thicker red border, described the situation at the end of the year. This picture also described the present situation.

The sequence below (figure 7) was presented if a participant started out with a rabbit population larger than 900 and a fox population below 50. The fox population grew to be larger than 50 by the end of the year, while the rabbit population were still above 900, though decreasing.

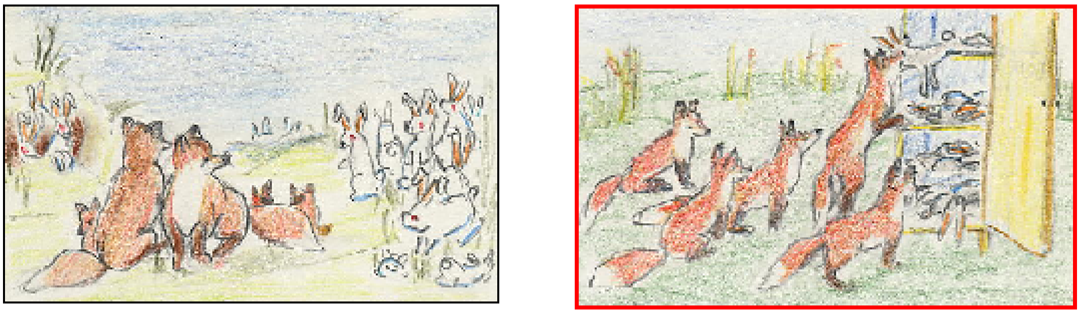


Figure 7.

A sequence of identical pictures indicated that the system had remained within the same quadrant all year. Figure 8 illustrates a case where there were too few foxes to prevent the rabbit population from growing (foxes < 50, rabbits > 900). Despite the abundance of food, the fox population did not grow larger than 50 during the year, leaving the rabbit population to increase even more.

Figure 8.

Procedure

The participants were randomly split into three groups of eight; four males and four females in each group. One group received the version with pictorial information of population sizes together with line graphs (the first condition), another group received the pictorial information describing the actual conditions for the rabbits and foxes together with the line graphs (the second condition), and the third group received only the line graphs (the control condition). All of the participants were tested individually.

The participants were introduced to the interface and received the task description in writing, which they were allowed to keep during the whole session. In the conditions with pictorial information, the participants also received a sheet with the pictures used together with a description of how they were to be interpreted. The experimenter also went through this information together with the participant before the simulation was started. The participants were asked to verbalize their thoughts during the session, and the session was recorded on audiotape (with their permission). These verbal data were collected for purposes external to the present study.

There was no time pressure. The participants decided themselves when to let a new year pass. There was no limit on the number of trials. The participants were allowed to continue until they had learned how to accomplish the task. After 45 minutes, the participants were allowed to decide whether they desired to give up or wanted to continue. If they decided to go on, they could continue for another 15 minutes. After that they had to stop.

Throughout the experiment, the researcher remained in the room to answer direct questions only, to decide when the participants had reached the goal, and, if needed, to provide encouragement to continue. The task was considered completed when the participants had figured out how to behave to reach equilibrium and were able to repeat the performance on request.

After questioning the participants about their beliefs concerning what talents, knowledge, or earlier experiences that might facilitate task completion, their educational background, and their final grades in math and Swedish from comprehensive school, the session was terminated.

Results

The experimental manipulation produced no performance differences between the groups. The hypothesis that the pictures describing the actual situation would facilitate task completion was not supported by the outcome. Three (3) of the subjects who received population sizes as pictures with the graphs, three (3) of the subjects for whom pictures of the prevailing situation supplemented the graphs, and two (2) of the subjects in the control group, succeeded at the task. Only 8 out of the in total 24 subjects, one third of the total sample, solved the task.

Half (6) of the male participants solved the task, but only 2 of the 12 participating women ($\chi^2 = 3.00$, $p = .08$). This replicates a finding by Jensen and Brehmer (submitted), where all four of the participating men succeeded at the task, but only four of the eleven participating women. Combining the two data sets yields a significant gender difference in favor of the males $\chi^2 = 6.62$, $p = .01$). Ten (10) of a total of 16 males solved the task, but only 5 of the 23 women.

The 24 participants in the present study were divided into groups of low and high performers in math. Those who had earned grade 3 or below were considered low math performers, and those with grades 4 and 5 were considered high math performers. (The Swedish grading system uses a 5-point scale ranging from 1 = “very low performance” to 5 = “excellent performance”). Of the 10 low math performers only one succeeded at the rabbits-and-foxes task, but half (7) of the 14 high performers did. Math grades from comprehensive school were significantly related to performance on the rabbits-and-foxes task ($\chi^2 = 4.20$, $p = .04$). This did not explain the gender difference in performance, since an equal number of women and men belonged to the high math performers (7 males and 7 females), and consequently the same was true for the low math performers (5 males and 5 females). Grades in Swedish were not related to task performance.

Education in Sweden is generally publicly financed and exempt from fees. Most pupils attend the school closest to home (Skolverket, 2000). Until they leave comprehensive school at age 16, the vast majority of Swedish children have similar educational experiences. We assumed the final grades from comprehensive school to be a good measure of the participant's talents for math and Swedish (verbal skills). Beyond comprehensive school Swedish youth are split on different course programs of their own choice. Then task performance differences could be an effect of diversity in task relevant experiences, rather than "innate" talent.

Participants were grouped on basis of their educational background. If they had studied a science or technology program in upper secondary school they were included in the math-experienced group (10 subjects). Those who did not fit this category belonged to the non-math-experienced group. Two participants had taken math courses after completing a non-mathematical program in upper secondary school. They were considered having some math experience. There were no performance differences related to educational background. Four (4) of the 12 subjects in the non-math-experienced group, 4 of the 10 subjects in the math-experienced group, and none of the two subjects with some math experience, solved the task. Surprisingly, 8 of the 12 subjects with a mathematical background (in or after upper secondary school) were women. Educational background did not serve as an explanation to the gender difference in performance on the rabbits-and-foxes task.

Discussion

The rabbits-and-foxes task is apparently a difficult one, as indicated by the low success rate. Displaying the rabbits' and foxes' current circumstances did not seem to be helpful. To the question why men outperformed women, the present study offers no answer.

Starting with the question of the overall weak performance, the difficulty of the task was already known (Jensen & Brehmer, submitted), but what could explain the apparent uselessness of the pictorial information? The fates of the populations were displayed by line graphs in all conditions. If processing line graphs required a lot of effort from the participants, the pictures might have been disregarded out of mental economy considerations. Perhaps the pictures did not make any sense to the participants and/or failed to provide any essential information to them.

Graphs, as mathematics, can be efficient means for clear communication of dense information, but only to people familiar with the language (Larkin & Simon, 1987). Children frequently hold misconceptions and difficulties in the area of functions and graphs (Leinhardt, Zaslavsky, & Stein, 1990). College students, and even graduate students, can exhibit amazing difficulties in understanding rather simple line graphs (Shah & Carpenter, 1995).

When comparing good graph readers to poor graph readers among high school students, Maichle (1994) found no differences in the relative frequency of extracting point value or trend information. They did differ with respect to the complexity of the extracted information. Poor graph readers generated almost no longitudinal comparisons, neither with respect to individual point values, nor with respect to trends. Good graph readers made more references to larger perceptual units (Maichle, 1994).

Sometimes people can encode a portion of a visual pattern, a visual chunk, and automatically associate it with a quantitative fact or relationship. It is more of a pattern recognition process in which little interpretation is needed. There are situations, however, in which graph viewers must rely on more or less complex inferential processes. First, they may lack the knowledge to associate a visual chunk with what it refers to. They do not understand the graphical language. Second, individual visual chunks may not directly represent the desired information. When transforming information in a display is required to extract relevant information, the task becomes more difficult and interpretations are often inaccurate or incomplete. Finally, people's knowledge about how different visual features correspond to *conclusions* to be drawn from the graphs may influence their interpretation of data (Carpenter & Shah, 1998; Shah & Carpenter, 1995). It is like when reading you understand the text perfectly but fail to draw the conclusions intended by the author.

There were no indications of participants having problems making point readings or extracting simple trend information in the present study. They were all able to read the actual population sizes from the graphs, and they also understood that lines going up meant increasing and lines going down decreasing populations. This is precisely the information provided by the pictures used in the first experimental condition. If there is no problem extracting such information from a line graph, presenting the same data in pictorial format is superfluous. Aids ought to deal with the difficult parts, not the easy ones.

When using line graphs as tools to teach 12-year-olds economic concepts such as the demand and supply laws, post-testing revealed performance deficits partly stemming from difficulties understanding the laws, and partly from graph reading problems. Concepts and links providing useful hints were frequently disregarded. Sometimes the subjects added information to make the task more intelligible. Graphs might in fact hamper learning. If understanding graphs becomes a task in itself, attention is drawn from the issue under treatment. This poses a potential threat to the mastery of the material (Gobbo, 1994).

Jensen and Brehmer (submitted) found that ignorance of the dynamic aspect, in addition to the difficulties in performing indirect thinking, was a frequent mistake in the rabbits-and-foxes task. The present study confirmed this. Several subjects related the requested fox population at the start of the year to the rabbit population by the end of the year. They were, quite naturally, frequently confused by the results. They failed to think of how changes in the fox population during the year affect the rabbit population. Important information indicating which actions to take was ignored in a way similar to the children in Gobbo's (1994) study.

In the second experimental condition, the current circumstances for the rabbits and foxes were displayed together with the line graphs. This additional information appeared to be disregarded when it contradicted the participant's expectations. In particular, the picture presenting foxes, consuming the reserves (diminishing rabbit population) but still not starving, was confusing to several of the participants. When the rabbit population grew during the first simulated years, the participants in general responded by gradually increasing the fox population. When arriving at a fox population, which during the year reached a size large enough to turn the growth of the rabbit population into a decline, pictures changed from the one showing a few fat foxes with puppies surrounded by a crowd of rabbits to the picture of foxes consuming the rabbit reserves. Some participants were surprised that the fox population still increased. They seemed to expect a decrease in the rabbit population to be accompanied by an instant decrease in the fox population. Others were confused by the dramatically changing conditions implied by the pictures. Since there were only five different pictures, all, except the one representing the ideal equilibrium situation, were true within a rather wide range. This could give the impression of steady states and sudden jumps. Anyhow, many participants subjected to this condition paid the pictures a great deal of attention initially, but after confronting a situation like the one described above they deemed the pictures useless (at least to them). They ceased almost completely to look at the pictures and devoted all their interest to the graphs. The only way in which the pictures seemed to assist them was to tell when the goal was reached. Then, the participants reacted to the new picture appearing on the screen.

How a task is approached and represented depends a lot on how it is interpreted. Thompson (2000) compared the selection task to a task called the arguments task, which is quite similar to the evaluation task used by Evans and Handley (1999) and described in the introduction. In the arguments task, people are to evaluate a conclusion that is derived from a conditional statement. Necessity and sufficiency information is important in this task, as it is in the selection task. In the arguments task, when an explicitly given conclusion is to be evaluated, people do consider necessity and sufficiency information, while this is rarely the case in the selection task. In the selection task, reasoners are not asked explicitly to evaluate inferences. Consequently, they may not represent information relevant to evaluating inferences, such as necessity/sufficiency relations. The task is instead to identify cases that could potentially reveal violations of the conditional rule. To consistently solve the selection task regardless of context, a method of investigating *all* cards for their potential to confirm, contradict or their irrelevance to the rule should be applied. If the task is interpreted as one of investigating *only* those cases that could potentially violate the rule, it could explain the facilitating effect of deontic rules (expressing permissions or obligations) on selection task performance (Cheng & Holyoak, 1985; Thompson, 2000).

Human cognition is guided by considerations of relevance. Relevance is a product of the cognitive effects produced and the cognitive effort required by the information in question. The cognitive effect depends on importance and usefulness of the information in the current context. The greater the cognitive effect, the greater the relevance. The greater the cognitive effort demanded to extract some information, the lesser its relevance. People's attention is directed by more or less implicit cost-benefit estimations in an effort to maximize the relevance of the information processed (Sperber & Wilson, 1995; Sperber, Cara & Girotti, 1995).

If the selection task is to be solved by selecting *only* those cards which have the potential to violate the rule, the *p*- and the *not-q*-cards, that would be simplified by a rule which is interpreted as a denial of there being *p-and-(not-q)* cases. In order to maximize facilitation, both the effect and the effort side have to be considered. On the effort side, *p* and *q* should be chosen in such a way that *p-and-(not-q)* is easier to represent than *p-and-q*. On the effect side a context should be chosen in where knowing whether there are *p-and-(not-q)* cases is more vital than knowing whether there are *p-and-q* cases (Sperber, Cara & Girotti, 1995). An example used by Sperber, Cara and Girotti (1995) is the conditional rule: ”if a women has a child, she has had sex”. A virgin mother, *p-and-(not-q)*, were claimed easier to represent than a women who is a mother and has had sex. A virgin mother would be a remarkable incident and consequently causes greater cognitive effect than an ordinary non-virgin mother. A context were also invented where it actually might exist artificially inseminated virgins, and the subjects were asked to pretend they were journalists trying to find out the truth of that rumor. This was intended to make the subjects take an active interest in revealing virgin mothers. This version of the selection task yielded a 78% success rate (Sperber, Cara & Girotti, 1995).

When interpreting the rabbits-and-foxes task, few subjects misunderstand the task to reach equilibrium between the two populations, just as most people probably understand the requirement to choose the cards relevant for confirming or disconfirming the rule in the selection task. What most participants appear to be lacking in both task, is an understanding of what strategies to apply to be successful. In the selection task the best strategy is to investigate all cards for their potential to confirm or disconfirm the rule, and then select those that have such potential. In the rabbit-and-foxes task understanding, that reaching equilibrium is the same as reaching a state where *both* populations die and multiply at the same rate, is required together with a thorough consideration of how that is accomplished.

Understanding how the rabbit population affects the fox population appears to be the most difficult part of the rabbits-and-foxes task. Some illustrations that highlight this relationship, would perhaps lead to better performance. To achieve a high cognitive effect the importance of the relationship has to be highlighted. A pedagogic demonstration of the workings of the interacting populations would hopefully decrease the cognitive effort requirements. The pictures in the second condition were intended to fulfill such purposes, but apparently they failed to do so. More effort is probably needed to produce clear illustrations that are easy to understand, if a facilitating effect is to be achieved.

Pinker (1990) distinguishes between two types of mental representations important in graph perception and comprehension, the visual description and the graph schema. The visual description is the output from visual perception, which is a structural description of the scene. The visual description simply tells what the graph looks like, and is attainable by all sighted individuals. A graph schema embodies knowledge of what graphs are for and how they are interpreted. A graph schema translates the information found in the visual description into conceptual information, and directs the search for desired pieces of information. According to Pinker (1990), different levels of graph schemas exist, from general to more specific ones. A general graph schema is applied when a graph is less familiar to the viewer. More or less vague insights in how to deal with graphs in general are then employed. The good (line) graph readers in Maichle's (1994) study were proposed to possess a specific line graph schema, while the poor graph readers were assumed to be limited to a more generic (general) graph schema. Most high ability subjects, before reading verbal statements to be judged, checked relevant attributes of the line graph, identifying and naming the dimensions, units, ranges of values as well as some trends. Low ability subjects scarcely verbalized graphical information before reading the verbal statements. Consequently, they had to spend more time and effort in the verification procedure, localizing and identifying the graphical information needed to judge each of the verbal statements. The good graph readers quickly recognized which type of graph was currently being viewed, and in turn directed their attention to typical line graph information (Maichle, 1994; Pinker, 1990).

Berg and Phillips (1994) used Piagetian tasks to assess the development of mental structures in 7-11 graders. Subjects showing evidence of proportional reasoning ability did significantly better on many graphing situations such as choosing the part of the graph with the greatest "rate of change". Locating points on a graph without a grid was significantly related to horizontal/vertical frames of reference. Students who did not possess the logical thinking structures were more likely to depend upon, and be influenced by perceptual cues and less able to interpret or construct graphs correctly.

Students solving nondeontic selection tasks have higher scores on the Scholastic Aptitude Test (SAT) than students not solving them, while performance on deontic selection tasks are unrelated to cognitive ability. People solving the nondeontic tasks most likely succeed by approaching them analytically regardless of task context, as solving nondeontic tasks are clearly related to solving deontic ones. Those are also the cognitively abler subjects (Stanowich & West, 1998).

All in all, it appears to be a matter of superficial versus deep approaches to cognitive tasks, rooted in differences in intellectual ability as well as experience. A remaining concern is whether performance deficits on the rabbits-and-foxes task stems primarily from difficulties in graph reading or from problems with deduction. The former would be a problem in perceiving, while the latter would be a problem in processing. Maybe it is a bit of both, but that need to be sorted out.

The issue is of vital importance because line graphs (as well as other kinds of graphs) are generally considered unproblematic. They are used in newspapers and television as well as course materials in schools. Caution is called for when processing beyond mere point and trend reading is required, and when a graphing experienced audience cannot be taken for granted. An audience of educated grown-ups is no guarantee it can (Shah & Carpenter, 1995).

Most people appear to spontaneously use fairly superficial approaches to problem solving. This seems at least to be true in unfamiliar areas and with problems framed in unfamiliar ways. More analytical approaches could perhaps be achieved by training, which would familiarize people with the problems. Selecting exclusively highly intelligent people would also most likely result in enhanced performance. Presentations targeting ordinary people have better put the conclusion to be drawn directly beneath the viewers' noses.

The answer to the question posed in the title seems to be yes, explicit information is important. Furthermore, the expected interpretations and conclusions made from the information should follow suit and be explicit. This should be the case whether the task is dynamic or static.

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