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Effect of goal setting on the strategies used to solve a block design task

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ABSTRACT

In this experiment we studied the effect of goal setting on the strategies used to perform a block design task called SAMUEL. SAMUEL can measure many indicators, which are then combined to determine the strategies used by participants when solving SAMUEL problems. Two experimental groups were created: one group was given an explicit, difficult goal and the other was not given a goal. The two groups were comparable in their average visual–spatial ability. The results indicated no goal effect on the strategies, defined in terms of the combined indicators. However, the goal did have an effect on some of the indicators taken alone (total problem-solving time, total viewing time, and model-viewing frequency) but this was true only for subjects with a low cognitive ability. These findings demonstrate that setting a goal can have an effect on some strategy indexes used to assess performance on a visual-intelligence design task. This research has implications for defining intelligence-test instructions and educational requirements in school.

1. Introduction

1.1. Framework

The purpose of the present study, conducted in the framework of goal-setting theory (Latham & Locke, 2007), was to measure the impact of goals on performance and strategies used on intelligence tests. In a goal-setting perspective, many studies have shown that performance enhancement depends on strategies available for the task (Seijts & Latham, 2005). Here, we used a computerized tool to study performance and strategies on Kohs Block Design Task (Rozencwajg & Corroyer, 2002).

1.2. Goal-setting theory

For forty years now, empirical and applied research on goal setting have shown that individuals who set specific goals (e.g. the specific "recall ten words" rather than the vague "recall a lot of words") and difficult goals (e.g. goals that can be reached by only 10% of such individuals) obtain significantly better results than individuals who do not (Latham & Locke, 2007; Locke & Latham, 1990).

For Locke and Latham (2002), three main mechanisms explain this improvement: direction, energizing effect, and persistence. First, direction refers to goal-oriented behavior directed *at* goal-relevant activities, and *away from* goal-irrelevant activities. Second, having a goal leads people to make an effort to reach it. Third, with a goal, people maintain their effort level for a longer time, which is revealed by lower performance dispersion on the task (Locke & Latham, 1990).

Finally, the goal effect depends on the strategy used. When individuals can easily use a good strategy that they already know, then assigning a difficult goal will generally increase performance (Locke & Latham, 1990; Locke, Shaw, Saari, & Latham, 1981). However, when the individual does not have an effective strategy, assigning a difficult goal leads to a drop in performance (Earley, Connolly, & Ekegren, 1989; Huber, 1985; Kanfer & Ackerman, 1989; Wood, Mento, & Locke, 1987). For many researchers, this effect can be explained by strategy accessibility: when a straightforward, clearly-defined way of reaching the goal is available, having a goal enhances performance (Latham & Locke, 2007; Locke, 2000; Locke & Latham, 2002).

It has been shown elsewhere that the goal effect is a function of cognitive ability. Because a goal has a directional effect, as Locke and Latham (2002) and Latham, Seijts, and Crim (2008) explained, individuals with a lower cognitive ability benefit more from the assignment of a more difficult goal than do those with a higher cognitive ability. Higher-ability individuals do not need a goal to focus their attention on learning.

1.3. SAMUEL, a computerized tool for studying performance and strategies in Kohs Block Design Task

SAMUEL, derived from Kohs Block Design Task, was constructed in the general problem-solving framework of cognitive psychology, where the processes and strategies underlying performance on psychometric tests are analyzed (Rozencwajg, 2007; Rozencwajg & Bertoux, 2008; Rozencwajg & Corroyer, 2002; Rozencwajg, Schaeffer, & Lefebvre, 2010).

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In this task, subjects use red and white colored squares to reproduce two-dimensional, red-and-white square designs composed of geometric figures. This task is usually considered to be a general intelligence test highly saturated in factor *g* (*.66*) and highly correlated with IQ (*.71*). It is also an indicator of a cohort factor called "visualization" (Cattell, 1971).

The SAMUEL task involves copying four model designs consisting of geometric figures displayed on the left-hand side of the screen, using the red, white, and red-and-white squares shown at the bottom of the screen (see Fig. 1). The screen is divided into three main parts. On the left, the test design appears whenever the subject requests, and remains on the screen until the subject clicks on a square, at which point the design disappears. Below this, the subject can select a square (an all-red one, an all-white one, or one of four red-and-white ones each oriented in a different way) and drag it up into the black reconstruction area on the right to reproduce the design. The device records the subject's moves for later analysis.

All of the subject's actions (looking at the model design, putting a particular square with a specific orientation in a given place, removing it) are recorded automatically and timed. Based on these recordings, two strategy indexes can be calculated: anticipation (number of attempts) and model-viewing frequency. The anticipation index represents the extent to which the subject constructs the design using trial and error or was able to correctly fill all cells on the first try. For each cell in the design, one obtains a ratio of 1:1 if the cell was correctly filled on the first try, a ratio of 1:2 if the subject took two tries, a ratio of 1:3 for three tries, etc. If a cell contains an incorrect square in the end, regardless of the number of tries, the ratio for that cell is 0. The various ratios are added and the sum is divided by the total number of tries. For example, for a four-square design where the subject took one, three, and two tries to correctly fill the first three cells, respectively, and then filled in the last cell with the wrong square in a single try, the calculation would be $(1/1+1/3+1/2+0/1)/(1+3+2+1)=0.26$. The anticipation index varies between 0 and 1 (0 if the subject ended up with only incorrectly filled cells, 1 if all cells were correctly filled on the first try).

We used these indexes to assess the strategy implemented by the subject to perform the task. In the analytic strategy, subjects view the model frequently and their anticipation index is high. In the global strategy, subjects proceed by trial and error and their anticipation index is low. In the synthetic strategy, subjects look at the model less often and their anticipation index is high. Two temporal indexes were also calculated: total problem-solving time and total viewing time. The synthetic strategy leads to the shortest solving time. All SAMUEL indexes were calculated for each of the four designs (for more details, see Rozencwajg & Corroyer, 2002).

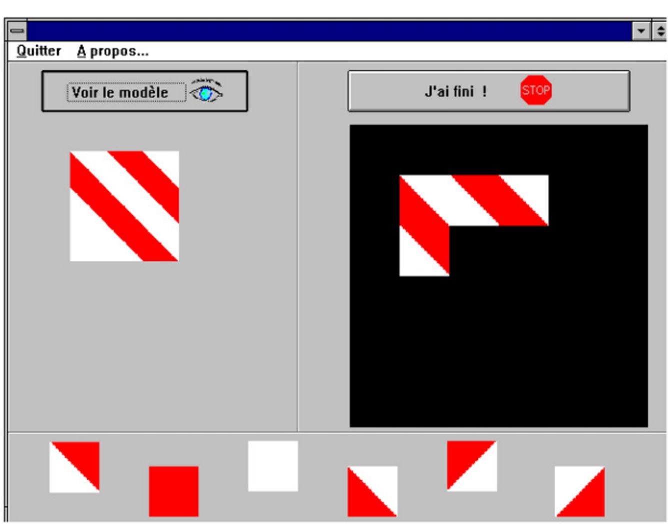

Fig. 1. SAMUEL screen during design reconstruction.

Although they have different efficiency levels, all three strategies can lead to a correct solution to the problem. The ability to find a solution is a necessary condition for the goal to improve performance. Our main hypothesis is that setting a goal will at least allow the subject to optimize his/her performance, even if he/she cannot change strategies radically by using a more effective one, namely, the synthetic strategy.

Concerning the instructions, there is no time limit in the standard administration of SAMUEL. Thus, the "specific, difficult goal" of SAMUEL is based on working speed. We hypothesize that having a temporal goal will decrease total problem-solving time. The effect of this difficult goal on the other strategic indexes is analyzed here while raising the following question: Will all of the indexes be affected in the same way by the temporal goal?

1.4. Performance and strategies on SAMUEL, and flexibility of closure

The findings of a previous study indicated that the score on the Group Embedded Figures Test (GEFT) – used to measure flexibility of closure – discriminates performance levels on block designs and also differentiates strategies used on the computerized task SAMUEL (Rozencwajg, Corroyer, & Altman, 2002). In particular, subjects who obtain a low score on the GEFT tend to have a low anticipation score and a longer total problem-solving time. On the other hand, there seems to be no link between model-viewing frequency and the GEFT. A low GEFT score is linked to global-strategy use, and a high GEFT score is linked to synthetic- and analytic-strategy use.

The problem solver's cognitive ability determines which strategy he/she will implement. Not all subjects are able to use the synthetic strategy. The effect of aging on strategies demonstrates this link: the synthetic strategy is no longer available to the elderly (Rozencwajg et al., 2005) unless experience compensates for the decline (Rozencwajg, Lemoine, Rolland-Grot, & Bompard, 2005).

1.5. Hypotheses

In SAMUEL, although there are several strategies, they can all lead to task success. We assumed here that the use of one strategy rather than another is related to the individual's cognitive abilities (Rozencwajg, 1991). Individuals who have strong visual–spatial abilities (high flexibility of closure) will use a synthetic strategy, because this is the simplest route for them. Similarly, individuals with low visual–spatial abilities will use a global strategy because for them, it is the easiest one. Whatever the strategy used, we can assume that the goal set can affect performance if the individual makes more effort.

Our first hypothesis is that having the explicit and difficult goal of working fast will enhance performance on SAMUEL by decreasing total problem-solving time. We will also analyze the effects of this goal on the strategic indexes (anticipation, model-viewing frequency, and total viewing time) and on strategy use.

This study should also allow us to examine the relationship between cognitive ability and goal setting. Our second hypothesis is that there will be an interaction between the task goal and the participant's cognitive ability (flexibility of closure) that will affect SAMUEL performance by decreasing total problem-solving time. More specifically, low-ability subjects will benefit more from having a goal than high-ability subjects will because the goal will help them direct their attention toward effective procedures likely to improve their performance. We will also analyze the effects of this interaction on the strategy indexes (anticipation, model-viewing frequency, and total viewing time) and on strategy use.

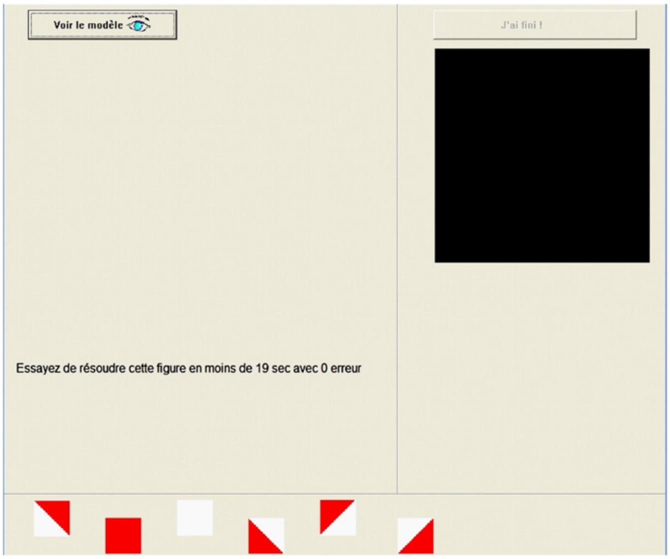

Fig. 2. Goal display in SAMUEL.

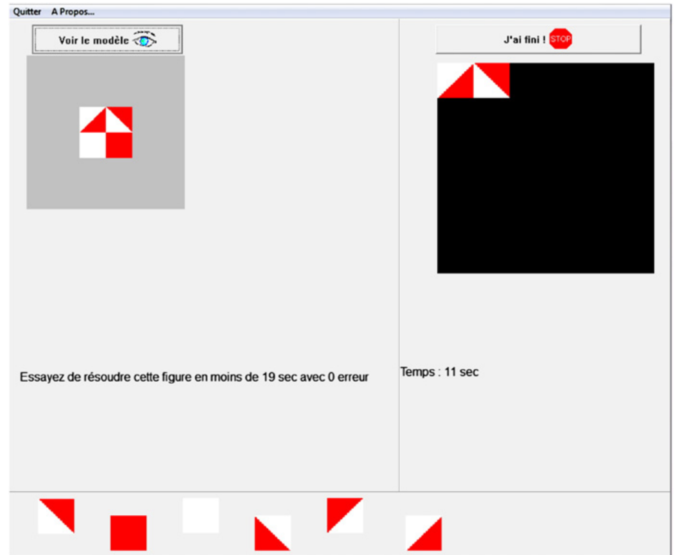

Fig. 3. Passage of time for goal condition in SAMUEL.

2. Method

2.1. Characteristics of the sample and experimental design

Eighty-seven female and seventeen male undergraduate students majoring in psychology or education participated voluntarily in the study.[1] Their mean age was 25 years (S.D. = 8). The 104 participants were randomly assigned to the no-goal (standard) condition or the goal condition. The no-goal group contained 51 participants and the goal group, 53.

2.2. Materials and procedure

2.2.1. SAMUEL, a computerized tool for studying performance and strategies in Kohs Block Design Task

SAMUEL was administrated individually. For each subject, several indexes were computed: total problem-solving time, anticipation, model-viewing frequency, total viewing time, and strategy employed.

2.2.2. Experimental manipulation of the specific, difficult goal

The group with a goal was compared to the group without a goal (standard administration of SAMUEL). In standard administration, the lower the total problem-solving time, the better the participant performs the task. We therefore chose to introduce a temporal goal to test its effect on performance. We used the norms of a previous study to determine the difficulty of the goal. These norms are based on total problem-solving time observed for 100 young adults with the same amount of education (Rozencwajg et al., 2002). As advocated by Locke and Latham (1990), a difficult goal must be attainable by only a small percentage of individuals. In our study, the temporal goal assigned to the goal group on each design was equal to the total problem-solving time achieved by only 10% of the reference group on that design (as determined in an experiment where participants were instructed to do their best; Rozencwajg et al., 2002).

During a given trial, the participant first saw the temporal goal displayed in the lower left quadrant of the SAMUEL screen (see Fig. 2). The goal was stated as follows: "Try to reconstruct this figure in less than *x* seconds with 0 errors", where *x* represented the number of seconds for that particular design.

When the person clicked on "View model", the internal timer of the program was triggered. The time since trial onset (in seconds) was shown in the lower right quadrant (see Fig. 3).

Finally, when the individual had finished reproducing the model, he/she was to click on the "I'm finished" button shown in the area above the reconstructed figure. Clicking on "I'm finished" caused the simultaneous display of the next goal in the lower left quadrant, and the time taken on the previous item (with a reminder of the previous goal) in the lower right quadrant (see Fig. 4). The latter information was displayed in the following sentence "Previous time: *x* sec (previous goal: *y* sec)", where *x* was the time taken by the individual on the preceding trial and *y* was the previous goal.

2.2.3. Group embedded figures test

The Group Embedded Figures Test (see Fig. 5) was administrated individually. The score varies between 0 and 18 points. The median observed here was 11 points. The subjects were classified into two groups, low cognitive ability and high cognitive ability, on the basis of whether their GEFT score was below or above the median.

3. Results

3.1. Preliminary experimental checks

Cognitive ability (GEFT score) was indeed found to be equivalent in the two experimental groups, i.e., the standard do-your-best group and the difficult-goal group ($F[1, 102] = 0.92$, $p = 0.34 > 0.05$, $R^2 = 1\%$) (see Table 1).

Secondly, the results confirmed the same cognitive-ability (GEFT) links to the strategy indexes (see Fig. 6) and to the strategy used (see Fig. 7).

3.2. Analysis of the goal effect (hypothesis 1)

Regarding the first hypothesis on the effect of the experimental condition (goal vs. no-goal), we observed a main effect on total problem-solving time ($F[1, 100] = 6.63$, $p < .05$, $CE^2 = 0.36$), on

[1] Acknowledgment — we would like to thank Monique Renard for assistance in data collection.

[2] Calibrated effects (*CE*) measure the magnitude of the effects from a descriptive standpoint (Corroyer & Rouanet, 1994; Rouanet, 1996).

Fig. 4. Time display solving and previous goal in the goal condition in SAMUEL.

model-viewing frequency ($F[1, 100] = 8.72$, $p < 0.01$, $CE = 0.41$), and on total model-viewing time ($F[1, 100] = 11.32$, $p < .001$, $CE = 0.44$). However, there was no effect on anticipation ($F[1, 100] < 1$, NS; see Fig. 6).

Hypothesis 1 was thus validated for the time indexes in the conditions where the goal was specified. Also the frequency of model viewing decreased when there was a difficult temporal goal. Participants who had a difficult goal looked at the model less frequently and for a shorter amount of time, which generally allowed them to work faster. Note that the goal had no effect on anticipation: subjects finished sooner without increasing or decreasing errors. They were therefore more efficient.

However, the difference in the viewing frequency was not sufficient to affect the overall strategy used. We found no effect of experimental condition on the synthetic-, analytic-, or global-strategy distances ($F[1, 100] < 1$, NS; see Fig. 7). We saw no change in strategy. Subjects merely optimized their strategy without changing it radically.

Concerning the impact of the goal on problem solving, we observed an effect on the within-subject standard deviation of total problem-solving time: the solving time of subjects with a difficult goal varied less across the four SAMUEL models (Fig. 8; $F[1, 100] = 5.36$, $p < .03$). Similarly, there was an effect on the within-subject standard deviation of model-viewing time: the viewing time of subjects with a difficult goal varied less across the four models (Fig. 8; $F[1, 100] = 7.25$, $p < .01$).

3.3. Analysis of the Interaction between cognitive ability and goal (hypothesis 2)

In line with our second hypothesis – that goal setting primarily benefits individuals who have a lower cognitive ability (flexibility of closure: GEFT < 11) – subjects in the no-goal experimental condition viewed the model longer than did subjects in the goal condition ($F[1, 45] = 8.23$, $p < 0.01$, $CE = 0.59$). Similarly, among the subjects with a low cognitive ability (GEFT < 11), those in the no-goal condition were slower at solving the problem than were subjects in the goal condition ($F[1, 45] = 4.07$, $p < 0.05$, $CE = 0.42$) (see Fig. 6). Each subject also had three scores, representing his/her distance from (1) the theoretical analytic strategy, (2) the theoretical synthetic strategy, and (3) the theoretical global strategy. These indices can be used as they are, but they can also serve to characterize each subject according to the strategy closest to him/her (for more details Rozencwajg & Corroyer, 2002). However, we observed no interaction for any of the distances from the strategies, whether synthetic, analytic, or global ($F[1, 100] < 1$, NS) (see Fig. 7).

Hypothesis 2 was validated only for the time indexes in the condition where the goal was specified.

Concerning the impact of the goal on performance, we obtained an effect on the within-subject standard deviation of total problem-solving time: the time taken to solve the problem by subjects with a difficult goal varied less across the four SAMUEL models ($F[1, 100] = 5.36$, $p < .03$), but this was only true for those participants

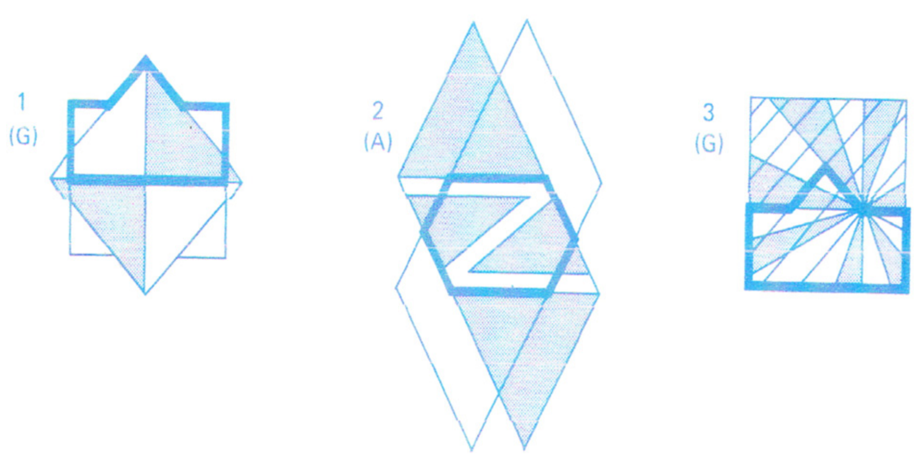

Fig. 5. Examples of the GEFT (Witkin, Ottman, & Raskin, 1971). The GEFT is a paper and pencil test.

Table 1
Means and standard deviations (in parentheses) of the GEFT score, by experimental group.

	N	GEFT score		N	GEFT score
No-goal condition	51	9.98 (4.61)	GEFT<11	25	6.04 (0.55)
			GEFT>=11	26	13.77 (0.47)
Goal condition	53	10.8 (4.35)	GEFT<11	22	6.45 (0.55)
			GEFT>=11	31	13.94 (0.39)

with a low cognitive ability ($F[1, 45]=4.93$, $p<.05$, $CE=0.46$) (see Fig. 8). Similarly, we observed an effect on the within-subject standard deviation of total viewing time: the amount of time spent viewing the model varied less across the four SAMUEL models when the subject had a goal ($F[1, 100]=7.25$, $p<.01$), but again, this held true only for subjects with a low cognitive ability ($F[1, 45]=6.56$, $p<.05$, $CE=0.53$) (see Fig. 8).

4. Discussion

Goal setting had no impact on anticipation, although it did affect the time indexes and the viewing frequency. Having a goal also had an impact on intra-individual dispersion: subjects with a difficult goal persisted in allocating effort to the task. The direction mechanism implied in goal setting (Locke & Latham, 2002) orients behaviors towards goal-relevant activities, assessed here in terms of model-viewing frequency: this possibility was used by the subjects to improve their performance. The effort mechanism involved in goal setting had an effect on the temporal indexes (solving time and model-viewing time). In line with the persistent effort engaged by having a goal, we observed a decrease in the intra-individual dispersion on the time indexes.

Furthermore, having a goal was beneficial for subjects with a low cognitive ability: when these subjects had a goal, they were quicker at solving the problem and viewed the model without making more errors; they were also more consistent in allocating effort to the task. This made them more effective. Having a goal did not change anything for subjects with a high cognitive ability.

Three strategies were identified in SAMUEL by combining the different indicators: model-viewing frequency, anticipation, solving time, and model-viewing time. Cognitive ability made only some strategies possible. The subjects with a low cognitive ability were not able to use the synthetic strategy. This inability showed up in the anticipation index: low-ability subjects found it difficult to anticipate the direction of the two-colored square and thus proceeded by trial and error. However, these subjects were able to optimize their available strategy by using the trial-and-error approach and by reducing model viewing. They were not able to change strategies, but they were more efficient. Note specifically that model-viewing frequency was not related to cognitive ability, but still allowed these problem solvers to be faster without making more errors. The goal therefore motivated these subjects to perform better. Their low cognitive ability, however, did not permit them to use the synthetic strategy.

It therefore appears that the frequency of model viewing, which is sensitive to goal setting, is not related to cognitive ability, and

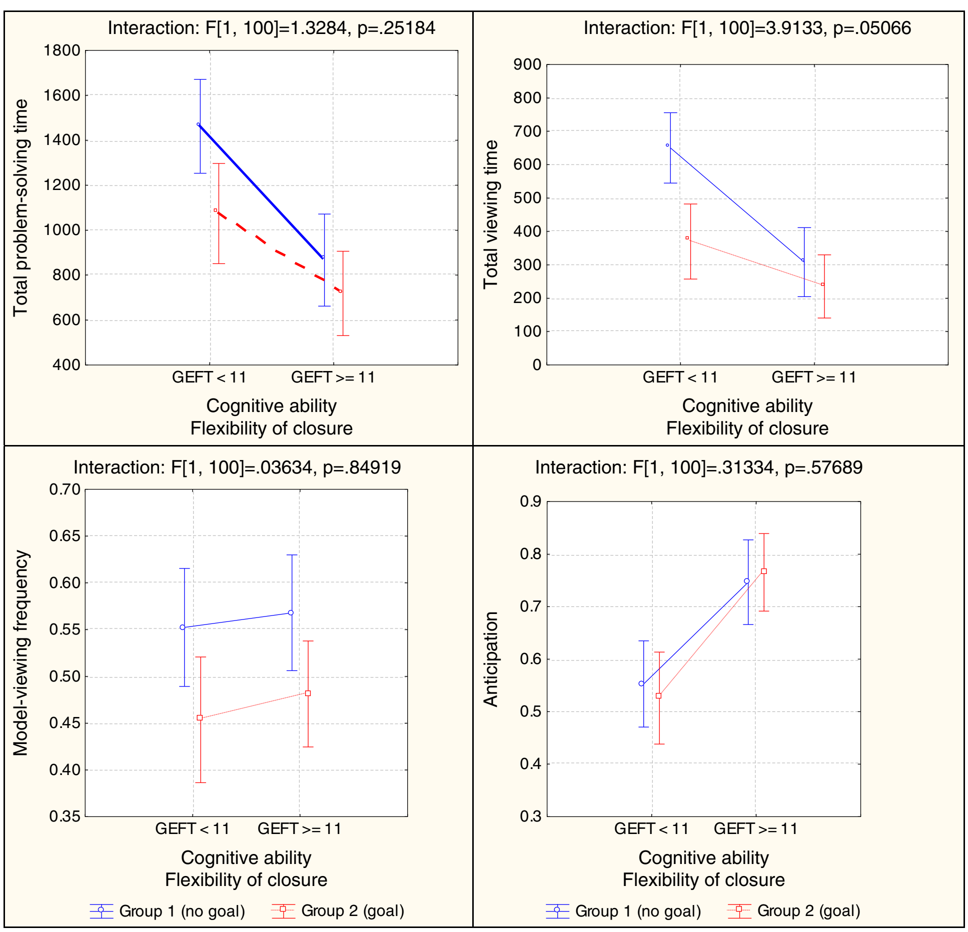

Fig. 6. Interaction between the experimental condition (goal vs. no goal) and cognitive ability on total problem-solving time, total viewing time, anticipation and model-viewing frequency.Note: total problem-solving time is equal to the total time taken to move all the squares onto the working area to copy the model. Total viewing time is equal to the total time spent looking at the model. Anticipation: the anticipated orientation of the squares composing the model is a score giving the number of attempts necessary to place each square correctly in the working area. Model-viewing frequency: the number of times the subject looks at the model design is used as a quantitative index of model viewing (Rozencwajg & Corroyer, 2002).

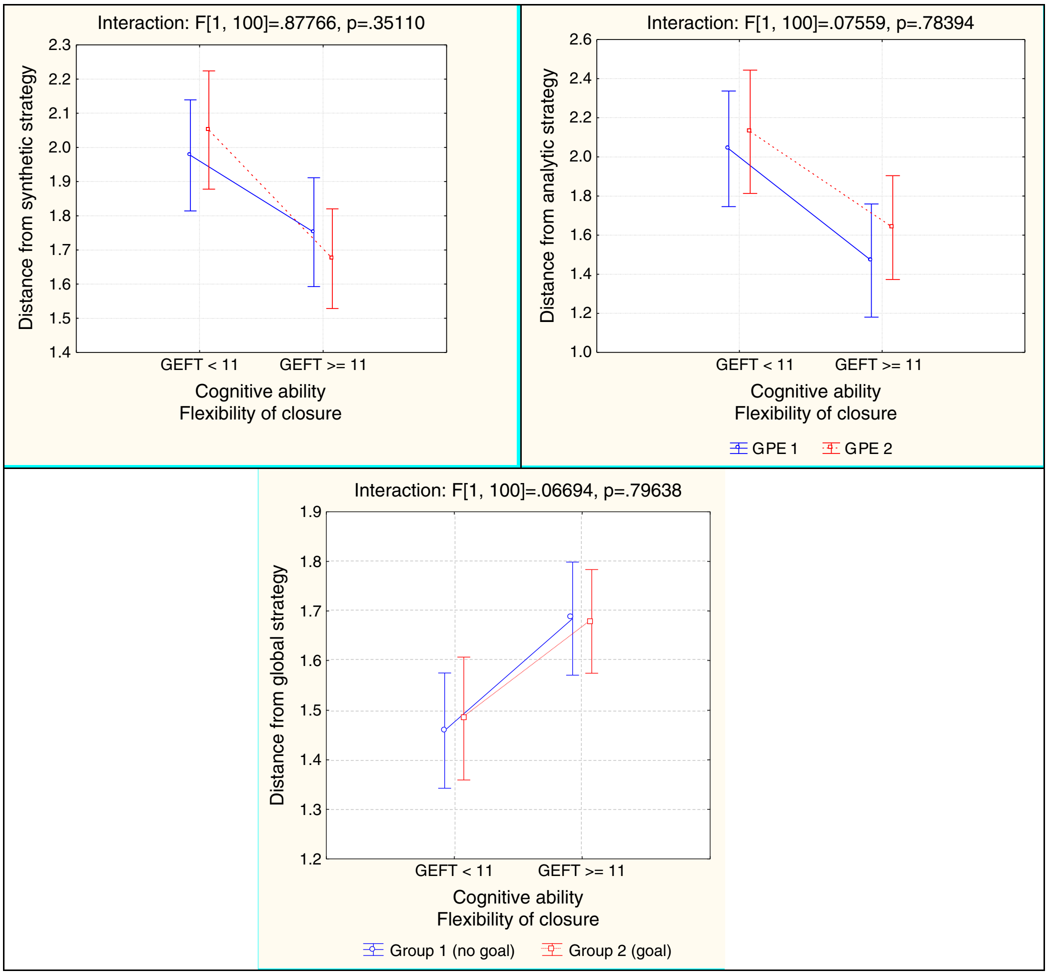

Fig. 7. Interaction between the experimental condition (goal vs. no goal) and cognitive ability, on the distances from the synthetic, analytic, and global strategies.Note: The strategy used – analytic, synthetic, or global – is identified by combining the different indices. A distance (the city-block distance, which is also known as the Manhattan distance) between each subject and each theoretical strategy is computed, and the subject is classified in terms of the strategy he/she preferentially used. The shorter the distance from theoretical strategy X, the more often strategy X was implemented (Rozencwajg & Corroyer, 2002).

conversely, that the anticipation associated with cognitive ability is not sensitive to the goal. It seems, then, that goal setting is effective for a factor that is unrelated to cognitive ability: the frequency of model viewing. The question this raises is: How do people go about reaching their temporal goal? In the goal-setting framework, a goal will be effective if the individual has the best strategy, in such a way that the effort applied is sufficient for achieving the goal (Latham & Locke, 2007; Locke, 2000; Locke & Latham, 2002). In the SAMUEL

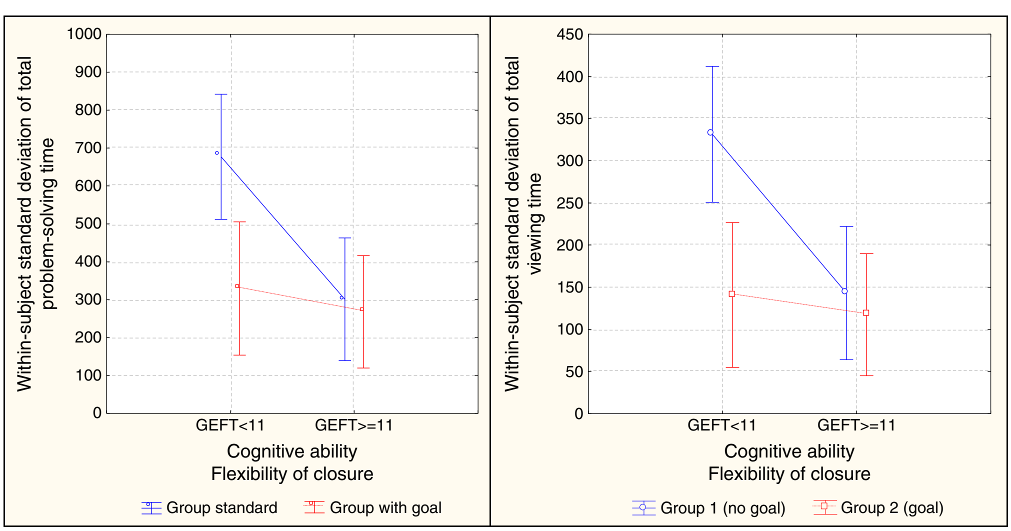

Fig. 8. Interaction between the experimental condition (goal vs. no goal) and cognitive ability, on within-subject standard deviation of total problem-solving time and total viewing time.

context, the best strategy is clearly the synthetic strategy, although other strategies also allow individuals to solve the problem. In line with the intelligence research, we showed that the implementation of one strategy rather than another is linked to cognitive ability. Moreover, the goal had no effect on anticipation, which was strongly linked to cognitive ability. It therefore seems unlikely that goals are able to affect the strategies adopted by individuals to solve figure problems.

However, in addition to having an impact on the amount of time spent viewing the model design, the goal also affected model-viewing frequency. Indeed, participants fully understood that to go faster they had to look less often at the model. This way of proceeding reduced problem-solving time and can therefore be regarded as a strategic indicator.

A more labile strategic aspect (looking at the model less often) was modified to adapt to the difficult goal. It seems, then, that anticipation is a more fixed aspect of strategy use. Having a goal thus seems to be able to affect some strategic variables but not others. A question arises at this level: Would the goal effect have been the same if the goal had not been based on time?

Other research is needed to confirm that a given goal always acts in the same way on the same indicators, and for all targeted aspects. It is possible that with the temporal goal used in our study, it was not necessary for participants to profoundly change their strategy in order to meet the task demands. To confirm these results, it is important to offer different kinds of specific and difficult goals, such as ones based on accuracy.

Even though if the goal had no impact on the strategies used – affecting only the model-viewing frequency, which it decreased – it is interesting to note that this frequency did not decrease enough to increase the implementation of the synthetic strategy. Indeed, other indicators involved in strategy use, such as anticipation, may have prevented this. If the goal pertained to accuracy, for example, would this confirm the lack of an effect on strategies?

This research has implications for defining intelligence-test instructions and educational requirements in school. It would seem more effective to encourage low-ability subjects by assigning them specific goals, no matter how difficult. However, this is true only if the subject has the strategies available in his/her repertoire that will allow for improvement, as shown for the development of encyclopedic memory (Fenouillet & Lieury, 1996). As already demonstrated by Terborg (1976), having a specific, difficult goal will not only improve performance but will also optimize solving strategies. Laporte & Nath (1976), in text learning, have showed that improvement with a difficult goal was attributed to study persistence and changes in learning behaviors.

For Binet "academic ability involves something other than intelligence; success in studies is related to certain qualities that depend on attention, will, effort continuity" (translate from french, Binet & Simon, 1908, p. 75). The theory of goal setting has important implications, not only to instructions in intelligence tests, but also in academic requirements. Indeed it appears that the instructions used unknowingly by Binet in the verbal fluency task were perceived as a difficult goal intended to encourage children to better progress. The instructions given by Binet before starting were: "I have known children who have found more than 300 words!

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