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Postfailure Reflectivity/Impulsivity and Spontaneous Attention to Errors

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We tested the idea that paying close attention to errors leads to improved performance on an inference task. We operationalized "attention to errors" as postfailure reflectivity, the ratio of the mean postfailure and post-success latencies on a self-paced inference task, where the interstimulus interval was subject controlled. Subjects were 9-, 10-, 11-, and 12-year-old children ($N = 378$). Results reveal that (a) postfailure and reflectives show high cognitive performance during their initial exposure to the inference task; (b) postfailure impulsives have lower scores than postfailure reflectives on IQ, Raven, a test for attentional capacity, an arithmetic test, and teacher's evaluations in percentiles; and (c) "fast" versus "slow thinkers," as defined by Kagan's cognitive style construct, do not form homogeneous groups: fast–accurate children are postfailure reflective, and slow–inaccurate children are postfailure impulsive.

This study was designed to investigate the phenomenon of spontaneous learning from errors that may occur when children are engaged in inference. A crucial moment during the process of inductive inference seems to occur after several trials, when the child presumably realizes that stimuli are organized in conformity with some rule, share a unique combination of attributes, or otherwise combine into a known pattern. If the invariant to be induced, which is related to the problem solution, is complex (relative to the subject's available processing capacities), the problem solution might take some time, and it might require many trials with feedback. Transfer of learning to other instances of the same invariant does occur when the subject has learned generically (structural learning, strategy learning, or learning set) the solution. When this happens, the production of correct responses in the following trials becomes easier, and the subject attains a high proportion of correct responses.

What determines, then, the time lag between being exposed to the first stimulus and the discovery of the pattern definition, the moment when the pattern-generating rules are formulated with enough clarity to lead the subject to a transfer of learning and a high proportion of correct responses? There is a long tradition in the literature on induction (e.g., Holland, Holyoak, Nisbett, & Thagard, 1986; Popper, 1968; Tolman, 1932) suggesting that conscious analysis of errors, as anomalies of the current "theory" of pattern-generating rules, is an essential step in successful inductive inference.

The purpose of this study was to test the idea that paying close attention to acts or events that lead to errors improves the performance on inference tasks. If a sequence of inference items of the same type is self-paced, the length of time that a child spends on reexamining an item after receiving feedback (and before requesting the next stimulus) may be a measure of the child's attention to the circumstances of his or her error, and could serve to measure self-correcting, executive processes that monitor attention to errors. This is particularly so when the child habitually spends more time reexamining the item after negative ("wrong") feedback than after positive ("right") feedback. Following this rationale, we defined a measure of attention to errors based on the subject-controlled intertrial interval (i.e., time elapsed between reception of feedback and the child's request for the next stimulus). *Postfailure reflectivity* is the ratio between the mean postresponse latency following failure and the mean postresponse latency following success, both measured on a self-paced inference task. This operational definition of executive processes for self-correction that monitor attention to the circumstances of errors (for short, *attention to errors*) affords an experimental test of our first hypothesis: high postfailure reflectivity is related to high inferential ability and quick coping with inferential tasks. We argue that children who spend time attending to errors during the initial encounter with a novel inference task should have good intratask learning and should score higher on subsequent items than children who do not spontaneously attend to their errors under these circumstances.

We also contend, and this is our second hypothesis, that the previous prediction (i.e., the first hypothesis) is not caused by inability to learn on the part of children with low postfailure reflectivity, low inferential abilities, and slow intratask learning, but it is due to superior mental-attentional executive monitoring in children with a style of functioning characterized by high postfailure reflectivity, high inferential abilities, and fast intratask learning. The superior executive know-how of these children leads them to reexamine the task after each error, which produces a high mean postresponse latency after

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failures, relative to their mean postresponse latency after successes. To test the claim that children who exhibit a low mean postresponse latency after failures, relative to successes, do so because they suffer from executive deficiencies (possibly caused by inadequate executive-learning opportunities), but that these children are otherwise developmentally normal, we used an experimental paradigm inspired by Vygotsky's concept of a zone of proximal development and related to methods of dynamic assessment (e.g., Day, 1983; Vygotsky, 1978). In our methodology we presented successively two different but related inferential subtasks. In the first subtask, encompassing the entire first part of an inferential pattern recognition (PAR) task, subjects were given one relevant cue dimension to guide their task solution; in the second subtask of PAR they received multiple (two or three) informationally redundant cue dimensions to guide their solution. Under these testing conditions we expected that children with high postfailure reflectivity would be more accurate in solving inferential problems and would show fast intertrial learning and higher performance scores in the first subtask (Hypothesis 1), but that children with low postfailure reflectivity and low scores during the first subtask would catch up with them during the second subtask—where the multiplicity of redundant cues makes it easier to notice and infer the proper periodic pattern (this is a test of the second hypothesis).

Our concept of postfailure reflectivity might be related to the dimension of preresponse reflection/impulsivity, which has long been proposed as an indicator of the manner, or style, of problem solving (Kagan, 1966; Kagan, Rosman, Day, Albert, & Phillips, 1964). The widely accepted operational definition of reflection/impulsivity is a double median split of score and response latency on the Matching Familiar Figures Test (MFFT); children whose response latency *and* score are above the respective medians (fast–inaccurate) are called "impulsive." Messer (1976) described the impulsive relative to the reflective child as being less attentive and more aggressive than the reflective child.

However, the reflection/impulsivity dichotomy suffers from several shortcomings, not the least being the existence of subpopulations that are fast–accurate and slow–inaccurate (Ault, 1973). Recent research has established that there are confounding factors such as IQ (Paulsen & Arizmendi, 1982) and the child's kind of response to an increase in the level of complexity of the problems (Lawry, Welsh, & Jeffrey, 1983). Other studies suggest that error scores, rather than the response latency, may be important in predicting the cognitive behavior of young children (Block, Gjerde, & Block, 1986). We argue that "fast thinkers" and "slow thinkers," as defined by Kagan's cognitive style construct, do not form homogeneous groups with respect to the amount of attention paid to errors, and thus regarding the number of total errors they produce. Children in each group may be postfailure reflective or postfailure impulsive, and this measure may predict their subsequent performance across inferential tasks. We thus tested a third hypothesis: Fast–accurate children will be postfailure reflective, and slow–inaccurate children will be postfailure impulsive.

In this study we did not directly investigate the issue of how postfailure reflectivity and impulsivity relate to Kagan's cognitive style. Although we did not use Kagan's MFFT measure of reflection/impulsivity, we believe that there is much merit in a reflection/impulsivity cognitive style and that our new methodology can illuminate important aspects of it. We will discuss this issue in detail in subsequent studies. Our goal here was to investigate, in a manner as spontaneous as possible, subjects' ability to extract lawfulnesses ("invariants") from experience and to react to error (mismatch between response expectancy and feedback) by producing an exploratory reaction intended to reexamine the problem and to find the "bug" in the previously inferred solution. We introduce a process model of reflective performance in the face of errors, a measure of this new sort of reflection/impulsivity, and some validating evidence.

Central Attentional Processes in Error Correction

Mental exploratory reactions geared to inference and learning have been described by Tolman (1948) in the behavior of rats encountering a "choice point," that is, a situation where they have run out of prelearned (automatized) executive plans and must evaluate the situation and orient themselves to synthesize a new plan about what to do next. Following Muenzinger (1938), Tolman called this behavior "vicarious trial and error" behavior—vicarious because its "trial and error" exploration is not behavioral but mental: reflective thinking geared to problem solving and caused by the need to decide the course of future action. Tolman's vicarious trial and error behaviors are special cases of Pavlov's exploratory reactions, in turn a particular case of orienting reactions. Sokolov (1963) proposed, and today this is generally admitted, that these behaviors are usually elicited by a mismatch between the subject's internalized model of the expected events and the actual feedback obtained in the situation. Spontaneous mental attentional processes of error correction are an instance of this behavior, quite common in humans but difficult to study under laboratory conditions. The rich current literature on executive processes and metacognition (meta-executives, i.e., conscious executive processes) has thrown much light on these phenomena (Brown, 1987; Kluwe, 1987; Pascual-Leone, 1983, 1984, 1987; Pascual-Leone & Goodman, 1979), although it has not yet provided good paradigms where *spontaneous* exploratory mental reactions can be easily investigated. We propose the postfailure reflectivity paradigm as a way of studying these spontaneous acts of executive processing. This paradigm consists essentially of an inferential context where the subject has attempted a problem-solving task and reached a conclusion; then the situational feedback, perhaps the teacher, indicates to the subject that the attained solution is wrong. These are the circumstances where mental exploratory reactions may occur, as indeed they do in many subjects who spontaneously produce acts of mental exploratory attention, mobilizing their executives (i.e., plans of action) and their mental attentional effort to reexamine the problem situation. These spontaneous acts of executive processing are characteristically nonautomatized and result from effortful, dynamic syntheses of the subject (Luria, 1973; Pascual-Leone, 1980, 1983, 1984, 1987).

We term *postfailure reflectivity* as the disposition to spontaneously generate these acts. This disposition promotes understanding of the self-propelling character of some children's and adults' learning, and may be relevant for explaining the spontaneity of some subjects' metacognitive (i.e., consciously reflective) activities. As numerous psychologists and philosophers have emphasized, full consciousness of a situation occurs only after some violation of expectancies in the situation, for example, when the subject experiences unexpected failure in cognizing it (e.g., Claparede, 1946; Piaget, 1976). This spontaneous movement of mental attention (i.e., Piaget's "decentration") toward conscious executive reflection (meta-executive processing) can be investigated quantitatively by measuring the subject's postfailure reflectivity.

The model of mental processing that we assume for this purpose is neo-Piagetian. We hypothesize that the measure of postfailure reflectivity is caused by executive/control processes (conceptualized as neo-Piagetian schemes, e.g., Case, 1985; Pascual-Leone, 1976, 1983, 1984) as follows: These executive schemes "notice" the mismatch between the originally expected solution of the problem and the situational feedback.The mismatch elicits an attentional decentration moving the mind back to the situational aspects that informed the original solution. The attentional decentration brings about a new search (mental computation) until a new solution to the problem is reached that agrees with the feedback, or until the subject's persistency fails. These spontaneous processes of mental check and comparison take time, and the time taken can be estimated by measuring the subject-controlled intertrial intervals in a self-paced inference task. We have defined two such measures, namely, postfailure reflectivity (PFR) and scaled postfailure reflectivity (SPFR).

$$\text{PFR} = \frac{\text{mean postfailure latency}}{\text{mean postsuccess latency}} \qquad (1)$$

For each of the two latencies measured during each trial (response and postresponse latencies), means are computed separately for those trials resulting in success and for those resulting in failure, over the whole task. The postfailure reflectivity (PFR) is the ratio between the means of the postresponse latency following failures and following successes, as shown in Equation 1. A problem solver who is postfailure reflective tends to spend more time immediately after the production of a failed performance (before initiating another trial) than after a successful performance. For example, the mean postfailure latency for a certain postfailure reflective subject may be 10 s, and his or her mean postsuccess latency may be 5 s, with a resultant PFR of 10 ÷ 5 = 2. For a postfailure impulsive subject, the means may be 6 s for postfailure and 5 s for postsuccess latencies, thus resulting in PFR = 6 ÷ 5 = 1.2.

In order to remove from this measure the source of variability corresponding to individual differences in the general propensity to take some time off after a performance and before the subject is ready for a new trial, we defined the scaled postfailure reflectivity (SPFR) score as shown in equation (2). This measure is obtained by scaling (dividing) the postfailure reflectivity (PFR) by the ratio between the means of the postresponse latency and the response latency. A problem solver who exhibits high values of *scaled* postfailure reflectivity may be said to be postfailure reflective relative to his or her disposition to spend time following versus prior to response.

$$\text{SPFR} = \text{PFR} \ / \ \frac{\text{mean postresponse latency}}{\text{mean response latency}} \qquad (2)$$

The latter ratio scales the subject's disposition to exhibit a postresponse latency relative to his or her disposition to exhibit a response latency (i.e., shows the amount of postresponse latency that is not quantitatively accountable in terms of simple response latencies—in terms of Kagan's impulsivity/reflectivity concept). Thus, the SPFR score should effectively eliminate all sources of variability in the PFR score that do not involve just the time taken by the mental exploratory reaction. If the imaginary postfailure reflective subject in the above example had a mean postresponse latency of 7 s and a mean response latency of 21 s, the resultant SPFR would be 2 × 21 ÷ 7 = 6. If the imaginary postfailure impulsive subject had a mean postresponse latency of 5.5 s and a mean response latency of 11 s, the resultant SPFR would be 1.2 × 11 ÷ 5.5 = 2.4.

The purpose of the present study was to determine whether attention to errors, as defined by these measures of postfailure reflectivity, exists in children, and, if so, to establish that these postfailure reflectivity measures are related, as they theoretically should be, to children's intellectual and mental capacity measures across content domains.

Method

Subjects and Tests Used

Subjects were students in Grades 4–7 in five public schools in Arad, a town in southern Israel. We tested an unselected sample of 378 subjects aged 9 (n = 131), 10 (n = 99), 11 (n = 79), and 12 (n = 69). Scores for the Israeli version (Orter, 1980) of an IQ test (M = 106.1, SD = 11.5) and of the Raven Progressive Matrices (Raven, 1960; M = 32.5, SD = 8.6) were available from the general tests administered to children by the Psychological Service of the Ministry of Education. These tests are administered to all students in Arad at the beginning of their third grade in school. Scores were also available for the TOAM computer-based drill and practice in arithmetic (Osborne, 1984). These scores show students' achievement in terms of months ahead or behind expected grade level. Teachers provided evaluations of students' general level of intellectual functioning (*not* level of academic achievement) in percentiles. Finally, the Figural Intersection Test (FIT) for mental attentional capacity (Pascual-Leone & Ijaz, 1989) was group administered. The PAR task, whose score (proportion of correct responses) constituted one of our main variables, is a computer-based inference task where stimuli are patterns of vertical bars with varying colors and heights, repeating in "blocks" or periods. They may also be accompanied by tones of varying pitch. The subject is shown one design at a time and must decide whether it is periodic (i.e., "correct") or whether it contains "a mistake," namely, either a "displaced" color (or height, etc.) or an "illegal" color (or height, etc.). PAR included 80 trials, 20 each of colors, heights, colors + heights, and colors + heights + sounds, shown in this order. The first 40 trials constituted subtask 1 (unidimensional cues) and the next 40 trials constituted subtask 2 (multidimensional cues) of the Vygotskian design described above. The base period was randomly chosen between 3, 4, or 5 colors or heights. Figure 1 shows two stimuli that contain "mistakes" and where the periodicity is shown through varying heights.

The temporal structure of the PAR task was as follows: presentation of the stimulus, followed by the subject's response, right/wrong feedback, and the subject's demand for the next trial. For each trial, the computer recorded the response and postresponse latencies and the score.

We observed and took notes of children's behavior during the task. Some children's problem-solving behavior consistently included spontaneous private speech. Some of the most interesting comments were recorded in postfailure situations, and included the following: "What happened? Where did I go wrong?... That's right!" "Can I put the cursor in-between?...There is a line missing here!" "I didn't understand before." "Only now I figured it out." "A long one is missing here." "Look what they put instead of the missing one!" "With colors it is easy to see, here (heights) I have to really test." "So I understood correctly, now I know." Strategies used by children in the PAR task have been reported elsewhere (Shafrir & Ogilvie, 1989).

Figure 1. Two examples of height stimuli: (a) base period = 5 with an "illegal" height mistake (9th bar from the right), and (b) base period = 4 with a "displaced" height mistake (6th bar from the left).

PAR Scoring Measures

Three different PAR scores were computed for each subject: (a) the proportion of correct responses for the whole task (number of correct responses divided by 80); (b) the proportion of correct responses for subtask 1 of the PAR task (20 color and 20 height trials), that is, the number of correct responses during the first 40 trials divided by 40; and (c) finally, the proportion of correct responses for subtask 2 of the PAR task (20 color + height and 20 color + height + sound trials).

Postfailure reflectivity (PFR) and scaled postfailure reflectivity (SPFR) were computed using equations (1) and (2) separately for subtask 1 (trials 1 to 40) and subtask 2 (trials 41 to 80) of the PAR task.

Results and Discussion

Performance During the First and Second Subtasks of the PAR Task

To test our hypotheses, we divided the total sample by the median scaled postfailure reflectivity in subtask 1 (median = 7.64). Children whose scaled postfailure reflectivity was higher than the median were called postfailure reflective, and those whose scaled postfailure reflectivity was lower than the median were labeled postfailure impulsive. Table 1 shows the mean scores during the first and second subtasks for the younger (9 and 10 years) and older (11 and 12 years) children, for the postfailure reflective and impulsive groups.

A two-way Age (2 level) × Scaled Postfailure Reflectivity Group (2 level) analysis of variance (ANOVA) for the subtask 1 score showed main effects for both age, $F(1, 376) = 150.8$, $p < .0001$; and scaled postfailure reflectivity, $F(1, 376) = 31.7$, $p < .0001$; $MS_e = .015$. No Age × Postfailure Reflectivity interaction was found. A two-way Age (2 level) × Scaled Postfailure Reflectivity Group (2 level) ANOVA for the subtask 2 score showed main effects for both age, $F(1, 376) = 39.3$, $p < .0001$; and scaled postfailure reflectivity, $F(1, 376) = 56.0$, $p < .0001$; $MS_e = .0097$. Again, no Age × Postfailure Reflectivity interaction was found.

A three-way Age (2 level) × Scaled Postfailure Reflectivity Group (2 level) × Subtask (first and second) ANOVA for the PAR score, with repeated measures on subtasks, showed significant main effects for age, $F(1, 376) = 44.9$, $p < .0001$; scaled postfailure reflectivity group, $F(1, 376) = 132.6$, $p < .0001$; $MS_e = .019$; and subtask, $F(1, 376) = 1024.9$, $p < .0001$. There was a significant Subtask × Scaled Postfailure Reflectivity Group interaction, $F(1, 374) = 53.36$, $p < .0001$, but no Subtask × Age or Subtask × Age × Postfailure Reflectivity Group interaction, $MS_e = .0058$. These results show, with reference to our first hypothesis, that children who were initially postfailure reflective achieved a significantly higher performance during the first subtask (the harder part of the PAR task, because it offered only one relevant cue dimension) than their postfailure impulsive counterparts.

Table 1
Mean Scores and Standard Deviations for Subtasks 1 and 2 of the PAR Task for Postfailure Reflective and Impulsive Children, by Age Group

	Postfailure reflective				*Postfailure impulsive*			
	Young (*n* = 98)		Old (*n* = 90)		*Young* (*n* = 132)		Old (*n* = 58)	
Task	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Subtask 1	.74	.11	.78	.10	.58	.14	.64	.14
Subtask 2	.88	.09	.91	.07	.80	.13	.88	.09

Note. Subtask 1 is composed of trials 1 to 40; subtask 2 is composed of trials 41 to 80.

With reference to our second hypothesis, these results show that in the second subtask (which is an easier inferential task because of the multiplicity of relevant cue dimensions) postfailure impulsive children performed much closer to their postfailure reflective counterparts, as attested by the highly significant Subtasks × Postfailure Reflectivity Group interaction.

Figure 2 shows the mean cumulative score versus trial number for the two postfailure reflectivity groups. The performance lag of the postfailure impulsives behind the postfailure reflectives is better exhibited in Figure 3, which shows the slope of the cumulative score as a function of trial number. The differential performance of the two groups changed between the first and second subtasks. In the more difficult subtask 1 (trials 1 to 40), the postfailure reflectives showed much higher intertrial learning than the postfailure impulsives. In the easier subtask 2 (trials 41 to 80), the performance lag between the two groups closed. Whereas the postfailure reflectives were still performing better than the postfailure impulsives, both groups seemed to have reached their respec-

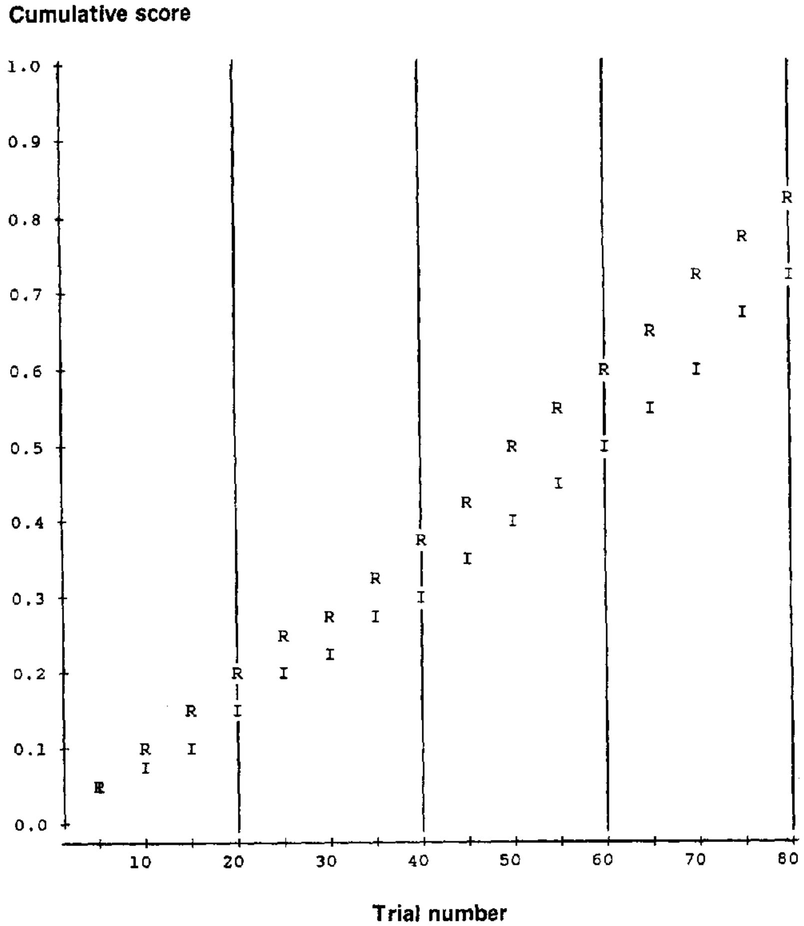

Figure 2. Mean cumulative scores on PAR as a function of trial number for the postfailure reflective group (R) and for the postfailure impulsive group (I).

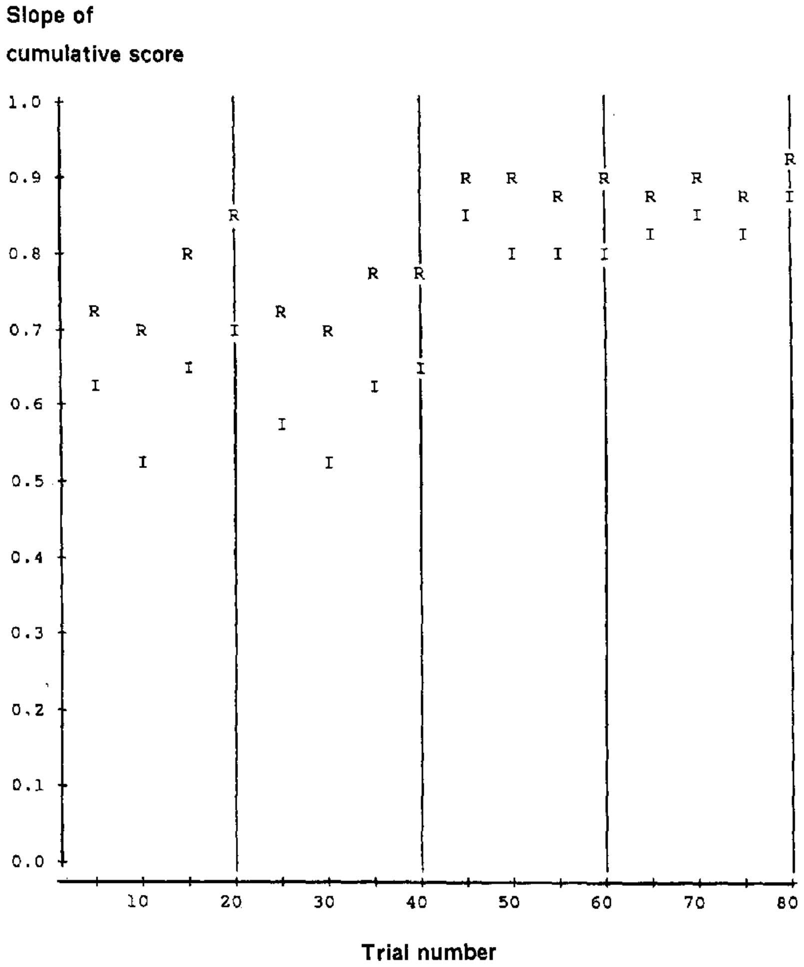

Figure 3. Mean slope of cumulative scores on PAR as a function of trial number for the postfailure reflective group (R) and for the postfailure impulsive group (I).

tive performance asymptotes. These data support our second hypothesis, namely, that under the facilitating conditions of subtask 2 (multidimensional cues), the postfailure impulsive children will exhibit good intratask learning.

Performance of Postfailure Impulsive and Postfailure Reflective Subjects on Other Tasks

Table 2 shows the scores on PAR, as well as scores on IQ (full scale), the Raven Progressive Matrices, the Figural Intersection Test (FIT), arithmetic drill and practice, and the teacher's evaluation in percentiles, for the postfailure reflective and impulsive children by age.

A two-way Age (2 level) × Postfailure Reflectivity Group (2 level) chi-square test showed significant differences between observed and expected cell counts, $\chi^2 = 11.94$, $p < .001$. As expected, more older children became postfailure reflective.

Table 3 shows the results of two-way Age (2 level) × Postfailure Reflectivity Group (2 level) ANOVAS for the scores (proportion of correct responses) on all 80 trials in PAR, as well as scores on IQ (full scale), the Raven Progressive Matrices, the FIT, arithmetic drill and practice, and the teacher's evaluation in percentiles. The developmental pattern in these results is consistent with Hypotheses 1 and 3. It indicates that our postfailure reflectivity measure would predict, as Kagan's reflection/impulsivity construct might, the high (reflective) or low (impulsive) performance of children in standard intelligence and developmental tasks, including tasks of mental capacity such as the FIT. Interestingly, our measure also predicts the level of teacher's cognitive-ability ratings, suggesting that the executive exploratory processes measured by postfailure reflectivity are indeed very central to the child's general performance.

Performance of "Slow/Fast Thinkers" Versus Postfailure Impulsives/Reflectives

In order to test the relationship between slow/fast response latency (i.e., Kagan's reflection/impulsivity) and high/low scaled postfailure reflectivity during the first subtask of PAR, the total sample was split into two groups by the mean response latency (i.e., preresponse latency for both successful

Table 2
Mean Scores and Standard Deviations on PAR, IQ, Raven, FIT, Arithmetic Drill and Practice, Teacher's Evaluation, for Postfailure Reflective and Impulsive Children, by Age Group

	Postfailure reflective				Postfailure impulsive			
	Young ($n = 98$)		Old ($n = 90$)		Young ($n = 132$)		Old ($n = 58$)	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Score	0.81	0.09	0.84	0.07	0.69	0.12	0.76	0.10
IQ	108.4	11.4	105.3	12.3	102.2	11.3	102.2	9.5
FIT	4.9	1.1	5.4	1.0	4.4	1.2	5.1	1.2
Raven	33.6	6.3	31.6	7.5	28.0	8.4	31.1	7.5
Teacher[a]	65.6	23.9	47.9	30.1	48.1	29.6	38.8	24.8
Arithmetic[b]	−1.7	10.8	−4.7	13.6	−7.3	8.9	−9.0	13.4

Note. Score = proportion of correct response on all 80 trials of PAR. Raven = Raven Progressive Matrices; FIT = Figural Intersection Test.
[a] Scores are in percentiles. [b] Scores are in terms of months ahead or behind expected grade level.

and failed performance). The "fast-thinkers" group included children with mean response latency below the median for their age (medians were 11.73, 11.55, 11.18, and 11.26 s for children 9, 10, 11, and 12 years old, respectively). Similarly, the "slow-thinkers" group included children with mean response latency above the median for their age. Each of these two groups was subdivided into postfailure impulsives and postfailure reflectives, according to a similar criterion as above: Children were placed in the postfailure impulsive group if their scaled postfailure reflectivity during the first subtask of PAR was lower than the median for their age (medians were 7.03, 6.97, 7.95, and 9.86 for children 9, 10, 11, and 12 years old, respectively). Similarly, the postfailure reflective group included children with mean SPFR during the first subtask of PAR above the median for their age. Finally, each group was split into "younger" (9- and 10-year-olds) and "older" (11- and 12-year-olds) groups.

Table 4 shows the descriptive statistics for the fast and slow thinkers. Table 5 shows the results of a three-way Age (2 level) × Response Latency Group (2 level) × Postfailure Reflectivity Group (2 level) ANOVA. There were no Age × Response Latency, Age × Postfailure Reflectivity, or Age × Postfailure Reflectivity × Response Latency interactions. The Response Latency × Postfailure Reflectivity interactions for the scores on PAR, IQ, the Raven, teacher's ratings, and arithmetic drill and practice showed that the highest scoring group on all these measures included children with response latencies lower than the median for their age group and scaled postfailure reflectivity higher than the median for their age group.

It should be noted that the large *F* ratio of 15.0 for the PAR score for latency groups is the result of relatively large contributions by two groups—the higher scores of a large number of older slow thinkers and the lower scores of a large number of younger fast-thinkers (see Table 4).

These results indicate, as postulated by Hypothesis 3, that the fast and slow thinkers are not homogeneous groups: Fast–accurate children are postfailure reflectives, and fast–inaccurate children are postfailure impulsives; slow–accurate children are postfailure reflectives, and slow–inaccurate children are postfailure impulsives.

Conclusions

In the introduction we put forward three different hypotheses that together relate postfailure reflectivity to both spontaneous, intentional executive-exploratory reactions (i.e., mentally effortful, willful corrective mental exploration and learning) and to Kagan's notion of a reflection/impulsivity cognitive style. These hypotheses were as follows: *Hypothesis 1*: High postfailure reflectivity accompanies high inferential ability and low postfailure reflectivity accompanies low infer-

Table 3
F Ratios for Two-Way Age × Postfailure Reflectivity/Impulsivity Group Analysis of Variance for the Total Score on PAR and for Other Test Measures

Measure	Score	IQ	Raven	FIT	Arithmetic drill and practice[a]	Teacher evaluation[b]
REF	132.6***	16.4***	15.6***	19.5***	15.8***	20.4***
Age	45.0***	*ns*	*ns*	26.6***	*ns*	8.3**
REF × Age	*ns*	*ns*	6.3*	*ns*	*ns*	*ns*
MS_e	0.0097	127.8	56.5	1.32	129.7	749.7

Note. REF = scaled postfailure reflectivity/impulsivity group; Score = proportion of correct response on all 80 trials of PAR; FIT = Figural Intersection Test; Raven = Raven Progressive Matrices
[a] Scores are in terms of months ahead or behind expected grade level. [b] Scores are in percentiles.

Table 4
Mean Measures and Standard Deviations on Various Tests for Fast and Slow Thinkers

	Postfailure impulsive				Postfailure reflective			
	Young (n = 76)		Old (n = 47)		Young (n = 38)		Old (n = 24)	
Test	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Fast thinkers								
Age	9.64	0.58	11.73	0.53	9.74	0.66	11.56	0.58
Latency	8.01	1.95	8.43	1.62	10.19	1.24	9.39	1.39
SPFR	4.78	2.23	7.11	3.40	15.79	8.66	19.34	9.31
Score	0.67	0.12	0.77	0.12	0.81	0.08	0.86	0.06
IQ	103.9	11.5	103.2	8.5	110.5	12.7	113.7	12.1
FIT	4.25	1.40	5.19	1.31	4.84	1.41	5.46	1.32
Raven	30.32	8.38	31.87	6.97	33.95	8.49	35.25	8.31
Teacher evaluation[a]	50.75	29.65	41.88	27.29	66.24	23.69	63.33	27.70
Arithmetic[b] drill and practice	−6.5	8.0	−8.0	13.5	−1.0	12.1	1.6	15.0
Slow thinkers								
Age	9.71	0.62	11.64	0.44	9.66	0.64	11.71	0.55
Latency	15.11	3.30	13.86	2.11	16.34	4.12	16.11	4.60
SPFR	7.15	2.25	9.92	4.40	16.39	9.51	22.22	13.77
Score	0.72	0.10	0.78	0.08	0.79	0.10	0.84	0.08
IQ	99.9	9.4	101.8	9.0	105.5	11.5	101.5	12.2
FIT	4.15	1.16	5.19	1.31	4.53	1.43	4.88	1.39
Raven	26.49	6.44	31.87	6.97	32.36	6.71	30.45	6.81
Teacher evaluation[a]	42.15	29.39	41.88	27.29	61.83	26.24	41.86	33.42
Arithmetic drill and practice[b]	−9.7	8.3	−8.0	13.5	−2.8	10.7	−6.7	12.9

Note. Latency = response latency (seconds); SPFR = scaled postfailure reflectivity; Score = proportion of correct response on all 80 trials of PAR; FIT = Figural Intersection Test; Raven = Raven Progressive Matrices.
[a] Scores are in percentiles. [b] Scores are in terms of months ahead or behind grade level.

ential ability. *Hypothesis 2*: The low inferential ability of children with low postfailure reflectivity is not caused by intrinsic developmental deficiencies (e.g., maturational deficiency in the reserve of mental capacity). Rather, it is caused by an extrinsic executive deficiency resulting from lack of prior executive learning opportunities. *Hypothesis 3*: When the usual response latency is considered, as Kagan did, from an individual-differences perspective, the anomalous cases in terms of Kagan's impulsivity/reflectivity model can be explicated by our postfailure reflectivity model—fast–accurate children are postfailure reflective and slow–inaccurate children are postfailure impulsive.

A significant Subtask × Scaled Postfailure Reflectivity Group interaction was revealed in Table 1 and the accompanying results of the two-way Age (2 level) × Scaled Postfailure Reflectivity Group (2 level) ANOVAs for the scores on subtasks 1 and 2, and a three-way ANOVA, Age (2 level) × Scaled Postfailure Reflectivity Group (2 level), and repeated measures on the first and second subtasks of the PAR task. These results support our first hypothesis, because they show that children who were initially postfailure reflective achieved a significantly higher level of mastery during the first half of the PAR test relative to children who were initially postfailure impulsive. The three-way ANOVA with repeated measures also lends support to Hypothesis 2, because it shows that after some executive learning practice in subtask 1, postfailure impulsive children performed in subtask 2 nearly as well as did postfailure reflective children.

Table 5
F Ratios for Three-Way Age × Response Latency Group × Postfailure Reflectivity Group (2 × 2 × 2) Analysis of Variance for the Total Score on PAR and for Other Test Measures

Measure	Score	IQ	Raven	FIT	Teacher[a] evaluation	Arithmetic[b] drill and practice
Age	43.5***	*ns*	*ns*	26.6***	8.2**	*ns*
LAT	15.0***	9.4**	6.0**	*ns*	*ns*	*ns*
REF	89.2***	11.9***	12.3***	8.9**	18.3***	17.9***
LAT × REF	3.7*	14.1***	8.7**	*ns*	4.1*	7.1**
MS_e	.01	122.5	55.6	1.32	760.4	127.2

Note. LAT = Response latency group; REF = scaled postfailure reflectivity group; Score = proportion of correct responses on all 80 trials of PAR; FIT = Figural Intersection Test; Raven = Raven Progressive Matrices.
[a] Scores are in percentiles. [b] Scores are in terms of months ahead or behind expected grade level.
*$p < .05$. **$p < .01$. ***$p < .001$.

Tables 2 and 3 show that postfailure impulsive children scored significantly lower than postfailure reflectives on the PAR total task, and that they obtained low scores on IQ, the Raven Progressive Matrices, attentional capacity (FIT), teacher's evaluations in percentiles, and arithmetic drill and practice. These data indicate that postfailure reflectives exhibit, across tasks, high inferential ability relative to postfailure impulsives. These predicted findings correspond to our concept of postfailure reflectivity as being produced by a spontaneously activated "debugging" procedure (i.e., an exploratory mental executive that helps children reexamine and correct faulty internal plans).

Tables 4 and 5 show that fast thinkers who are postfailure reflectives scored higher than fast thinkers who are postfailure impulsives on IQ, the Raven, the FIT, teachers' evaluations, and arithmetic. Similar but less pronounced results occurred with slow thinkers. Analysis of variance (Table 5) revealed main effects for the fast/slow thinkers and postfailure impulsives/reflectives. These data support the third hypothesis, as explained above. Most intriguing are the Response Latency × Postfailure Reflectivity interactions for the scores on the PAR, IQ, the Raven, teachers' ratings, and arithmetic drill and practice (Table 5), which showed that the highest scoring group on all these measures included children with response latencies lower than the median for their age group and scaled postfailure reflectivity *higher* than the median for their age group. It appears that fast-thinking, postfailure reflective children possess high intellectual abilities.

In conclusion, the data show that postfailure reflectivity is an experimentally tractable measure of the mental executive exploratory reaction we have called *attention to errors*. Our concept of postfailure reflectivity supports Kagan's claim of a reflection/impulsivity cognitive style. These data were collected with a different, more precise methodology that used convergent operations. Although we have not directly used Kagan's measure, we used the error rates and response latencies in our PAR paradigm to re-create data patterns analogous to those reported in the reflection/impulsivity literature. Among the previously reported patterns, we found that reflection/impulsivity differences are less marked across cognitive tasks after 10 years of age. Another conclusion of our research is that postfailure reflectivity scores, particularly scaled postfailure reflectivity, are likely to be better and more powerful measures of reflection/impulsivity than Kagan's measure. These measures depend only on latencies and not on error rates, thus remaining close to the spirit of the concept of a cognitive tempo.

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