JOURNAL OF EXPERIMENTAL CHILD PSYCHOLOGY 47, 42–46 (1989)

REBUTTAL

Output Interference, Generic Resources, and Cognitive Development

V. F. REYNA AND C. J. BRAINERD

University of Arizona

There are five additional reasons for preferring output-interference explanations over the resources hypothesis: (a) Children's performance on fundamentally decerebrate tasks (e.g., tapping) is impaired by concurrent cognitive activity. (b) Dual-task deficits and memory performance are developmentally dissociated. (c) Available dual-task data are inconsistent with more than one version of the resources hypothesis. (d) Dependencies between children's memories and their reasoning are frequently caused by uncontrolled third variables (e.g., age). (e) Under more rigorous laboratory conditions, children's reasoning is normally independent of their remembering. © 1989 Academic Press, Inc.

Many considerations in our article favored output interference over resources as an explanatory principle. Thanks to the thoughtful commentaries on the article, we have noted five additional considerations that point to the same conclusion, each of which must be accommodated by future resource proponents. We draw out these matters in our seriatim rejoinders.

Bjorklund and Harnishfeger claim that covert motor responses are "difficult to discern" and that a "mental products" definition would be tantamount to obfuscation. Our reply to the second challenge is that even if outputs were defined as mental products, the problems inherent in measuring such a construct would be no more insuperable than they are for any other cognitive process—e.g., encoding or retrieval or, for that matter, resources (see Brainerd, 1983, 1985). Our reply to the first challenge is that subtle motor responses have long since yielded to precise experimentation. The technology for measuring a broad range of such responses (e.g., incipient articulation movements) has been in hand for the better part of this century. Naturally, refinements will be necessary

Send reprint requests to either author at College of Education, University of Arizona, Tucson, AZ 85721.

0022-0965/89 $3.00

for studying motor/cognition covariations. This is a problem worth tackling, however, because establishing a firm connection between tangible responses and occult cognitions would herald a methodological advance of the same order of magnitude as mental chronometry (Posner, 1978; Sternberg, 1966).

As Tolman taught us long ago, some crucial outputs are neither subtle nor difficult to measure; they are merely not recorded. This lesson applies to Bjorklund and Harnishfeger's reference to deficits that accrue in the postrecall phase when "there is little or no overt motor output." Although there is certainly less of the behavior of record (recall), our studies reveal that this is a period of intense ratiocination that is accompanied by acts such as hand clenching, paper crumpling, digging of fingernails into tables, moaning in frustration, and the like. One of our 7-year-old subjects struck himself smartly on the side of the head saying, "I'm trying to knock the last few words out through my ear." Our subjects seem to believe that such postrecall behavior will generate the intransigent items through some sort of response synergism (e.g., as when people are told to "say cheese" to promote smiling).

Next, we are rightly called to task for our predictions about difficulty and interference. We treat difficulty as only a *rough correlate* of interference, but the idea needs unpacking. A promising method involves training subjects to tap to an external signal while performing a concurrent memory task. Different groups receive different numbers of tapping signals, with our theory anticipating that difficulty (interference) grows as taps accumulate. Resource theory does not expect this because tapping is under external rather than mental control.

We are grateful to Bjorklund and Harnishfeger for supplying data that confirm our prediction of asymmetrical deficits. They dispute their data, however, on grounds of response-scale incommensurability and offer variance accounted for as a common scale. Unfortunately, the substitute measure is not satisfactory because it is chiefly controlled by reliability, not treatment effects. That is, what the alternative data suggest is simply that the tapping task is less reliable than the recall task. As for the scaling problem itself, procedures for dealing with it have been described (see Brainerd & Reyna, 1989).

Bjorklund and Harnishfeger finally appeal to span and M power data as the ultimate redoubt of resources. But this fortress is erected upon sand. First, dependencies between variables were never calculated in many studies. When M power measures (span) and reasoning measures (e.g., transitivity) have been shown to correlate, classic "third variables" have been left uncontrolled, with age being the most ubiquitous. As we have remarked elsewhere, when proper memory measures are used and essential controls are instituted, the prototypical outcome is reasoning/

remembering independence (Brainerd & Kingma, 1984, 1985; Brainerd & Reyna, 1988; Reyna, 1988; Reyna & Brainerd, 1987).

Guttentag also raises the issues of overt versus covert responses and difficulty as an interference index. Our earlier replies are apropos. His further remark that Bjorklund and Harnishfeger's new data may be rooted in task priorities is well taken. Fortunately, Friedman, Polson, and Dafoe (1988) showed that interference can still be estimated in the face of fluctuating task priorities. However, a series of studies like Bjorklund and Harnishfeger's is in order in which task-priority instructions are systematically manipulated.

Guttentag's key criticism emerges from his modification of the fireplace and air conditoner analogy. The nub of the criticism is that dual-task deficits are theory neutral, just "tools." We believe, on the contrary, that the interpretation of deficits turns on whether the resources view is correct and on the *version* of resources that one adopts. The favored idea in the dual-task literature is that tapping declines constitute savings that are transmitted to memory performance, so deficits are an *indirect* index of resource expenditures by memory. A more straightforward hypothesis is that deficits are a *direct* index of resource expenditures on tapping itself. Guttentag's own data are at odds with either definition.

In Experiment 1, deficits shrank with age, but memory performance was invariant. Under the savings scenario, younger children, who possess less memorial ability, were compensating more than older children. But this requires the implausible assumption that the intertask calibration mechanism is more highly developed in younger children! Under the second resource definition, there should also have been an age trend in memory performance under the dual-task condition: Larger tapping declines signal greater resource depletion, which leaves fewer residual resources to drive memory.

The denouement is that any definition of a common processing resource demands developmental dependencies between dual-task deficits and memory performance. The one unambiguously disconfirmatory result is developmental dissociation between the two, which is in fact what has been observed to date (see Bainerd & Reyna, 1989). As we have said, this outcome cannot be explained away by resorting to "third man" arguments, such as age interactions in compensatory mechanisms.

Chapman believes that output interference may account for dual-task deficits, but that other evidence supports "resource limitations in cognitive performance." We have analyzed the shortcomings of this same evidence elsewhere (Brainerd & Kingma, 1984, 1985; Brainerd & Reyna, 1988). It should be added that global measures of stage and attentional capacity do not establish "specific dependencies," and, instead, are subject to the same third-variable confounds that afflict the M power literature. Further, contrary to Chapman and Lindenberger (in press), premise memory

is known to be independent of transitive inference when spatial cues are controlled (Halford & Galloway, 1977; Kingma, 1981; Russell, 1981).

Chapman makes the instructive observation that "a motor task like finger tapping does not share a common pool of resources with memory performance." We concur. However, we think it is serendipitous that such a decerebrate task has been studied. Tasks without a significant intellectual component allow one to separate output interference from cognitive interference and to classify current developmental findings as due to the former because of the impossibility of the later.

Like Chapman, Howe and Rabinowitz admit the potential coexistence of both theories and construct an elegant model to illustrate the current indeterminacy of the two positions. Although the various options implemented in their model are all possible, they are not equally probable. Available data already alter the a priori probabilities of certain options. For example, most researchers now believe that information processing occurs in parallel but outputs are produced serially (Estes, 1988). Similarly, we have discussed evidence that competition for scarce resources does not occur. Once these aspects of the model have been adjusted to reflect present knowledge, output interference—in either the response-competition sense or the output-scheduling sense—becomes the most likely source of dual-task deficits.

The enduring lessons of Howe and Rabinowitz's model are that our theoretical commitments fashion our interpretations of data and that these commitments must be scrupulously spelled out if alternative explanations are to be given fair chances at confirmation. In other words, analysis of competing views requires more than casual nods to rival theories. It requires dispassionate contests in the arena of data.

In sum and in addition to the points covered in our article, we conclude that output-interference theory is preferrable to resources theory for five reasons. First, tapping, a thoroughly motoric activity with few cognitive ramifications, is dramatically affected by concurrent memory performance. Second, available developmental data show a complete dissociation between dual-task deficits and memory performance. Third, available developmental data are inconsistent with more than one definition of the resources construct. Fourth, reported dependencies between children's memories and their reasoning are often attributable to uncontrolled third variables. Fifth, when proper controls are imposed, children's reasoning and remembering are typically independent.

REFERENCES

Brainerd, C. J. (1983). Working-memory systems and cognitive development. In C. J. Brainerd (Ed.), *Recent advances in cognitive-developmental theory: Progress in cognitive development research* (pp. 167–236). New York: Springer-Verlag.

Brainerd, C. J. (1985). Model-based approaches to storage and retrieval development. In

C. J. Brainerd & M. Pressley (Eds.), *Basic processes in memory development: Progress in cognitive development research* (pp. 143–208). New York: Springer-Verlag.

Brainerd, C. J., & Kingma, J. (1984). Do children have to remember to reason? A fuzzy-trace theory of transitivity development. *Developmental Review,* **4,** 311–377.

Brainerd, C. J., & Kingma, J. (1985). On the independence of short-term memory and working memory in cognitive development. *Cognitive Psychology,* **17,** 210–247.

Brainerd, C. J., & Reyna, V. F. (1988). Generic resources, reconstructive processing, and children's mental arithmetic. *Developmental Psychology,* **24,** 324–334.

Brainerd, C. J., & Reyna, V. F. (1989). Output-interference theory of dual-task deficits in memory development. *Journal of Experimental Child Psychology,* **47,** 1–18.

Chapman, M., & Lindenberger, U. (in press). Concrete operations and attentional capacity. *Journal of Experimental Child Psychology.*

Estes, W. K. (1988). Toward a framework for combining connectionist and symbol-processing models. *Journal of Memory and Language,* **27,** 196–212.

Friedman, A., Polson, M. C., & Dafoe, C. G. (1988). Dividing attention between the hands and the head: Performance trade-offs between rapid finger tapping and verbal memory. *Journal of Experimental Psychology: Human Perception and Performance,* **14,** 60–68.

Halford, G. S., & Galloway, W. (1977). Children who fail to make transitive inferences can remember comparisons. *Australian Journal of Psychology,* **29,** 1–5.

Kingma, J. 91981). *Die ontwikkeling van quantitatieve en relationaele begrippe bij kinderen van vier tot twaalf jaar.* Unpublished doctoral dissertation, State University of Groningen.

Posner, M. I. (1978). *Chronometric explorations of mind.* Hillsdale, NJ: Erlbaum.

Reyna, V. F. (1988, May). *Reiterative versus reconstructive recall in opinion change.* Annual Nag's Head Conference on Judgment and Decision Making, Kill Devil Hill, NC.

Reyna, V. F., & Brainerd, C. J. (1987, November). *On the relationship between memory and judgment in opinion change.* Paper presented at the Psychonomic Society, Seattle, WA.

Russell, J. (1981). Children's memory for premises in a transitive measurement task assessed by elicited and spontaneous justifications. *Journal of Experimental Child Psychology,* **31,** 300–309.

Sternberg, S. (1966). High-speed scanning in human memory. *Science,* **153,** 652–654.

RECEIVED: June 7, 1988.