Processes and consequences of peer collaboration: A Vygotskian analysis

By: Jonathan R. H. Tudge

This is the peer reviewed version of the following article:

Tudge, J. (1992). Processes and consequences of peer collaboration: A Vygotskian analysis. *Child Development*, *63*(6), 1364-1379. DOI: 10.2307/1131562

which has been published in final form at http://dx.doi.org/10.2307/1131562. This article may be used for non-commercial purposes in accordance with Wiley Terms and Conditions for Use of Self-Archived Versions.

Abstract:

A sample of 162 children aged from 5 to 9 was pretested to discover each child's "rule" for predicting the movement of a mathematical balance beam. Children then worked alone, with a partner who used the same rule, with a partner who was more competent, or with a partner who was less competent. If partners' predictions differed, the dyad members were asked to discuss and reach agreement, but were not given feedback. All children were subsequently given 2 individual posttests. The results revealed that regression in thinking was as likely a consequence as improvement, both proving stable. Benefits accrued primarily to those whose partner was more competent, but understanding of the outcomes of collaboration required attending both to the nature of the rules (whether they allowed consistent or inconsistent prediction) and the shared understanding attained during the paired session.

Keywords: Dyadics | Reasoning | Dyadic relations | Collaboration | Cognition | Age groups | Child development

Article:

This research was conducted as part of a doctoral dissertation submitted to the Department of Human Development and Family Studies, Cornell University, and portions were presented at the annual meetings of the American Educational Research Association, Chicago, April 1991 and at the biennial meetings of the Society for Research in Child Development, Seattle, April 1991. Preparation of this paper was facilitated by the award of a National Academy of Education Spencer Fellowship. For their critical reading of earlier drafts, I wish to thank: Margarita Azmitia, Stephanie Behrend, Ellice Forman, Garrett Lange, Martie Skinner, Jim Wertsch, Paul Winterhoff, and some most helpful anonymous reviewers. My thanks also to Antoinette Levatich, Lara Schmitz, Masharell Mangum, and Paul Winterhoff for their transcribing and coding, and I would like to express my great appreciation to the children and staff of Central Elementary School, Ithaca, NY. Reprint requests should be sent to: Jonathan Tudge, Department of Human Development and Family Studies, University of North Carolina at Greensboro, Greensboro, NC 27412-5001.

Under what circumstances can pairs of children help each other improve their thinking while working together on a task? Can working collaboratively adversely affect children's thinking? Does it matter whether they have the same initial understanding of the task or differ in their levels of competence? What are the mechanisms that translate collaboration into more advanced thinking? These are the questions to be explored in this paper. My goal is to examine peer interaction from a Vygotskian perspective, focusing on both the outcomes and processes of collaboration.

Most research over the last 2 decades that has examined the relation between peer social interaction and cognitive development has been based on the theories of either Piaget or Vygotsky (for reviews see, e.g., Azmitia & Perlmutter, 1989; Tudge & Rogoff, 1989; Tudge & Winterhoff, in press). Scholars influenced by Piaget (e.g., Doise & Mugny, 1984; Murray, 1982, 1983; Perret-Clermont, 1980) view cognitive development as most likely to result from interaction when there is a difference in perspectives between peers (as opposed to adult-child dyads) that gives rise to arguments between them (sociocognitive conflict). According to Piaget (1959, 1977), children who have reached the concrete operational stage should benefit more from collaboration than their younger peers.

The typical Piagetian research paradigm in this domain features conserver-nonconserver dyads who are asked to reach agreement on conservation or spatial perspective problems and are then tested individually to determine whether the nonconservers have advanced. In this situation, the nonconserving members of dyads are highly likely to attain conservation, and continue to provide conservation responses up to a month later (Murray, 1982, 1983). Moreover, the conserving members do not regress as a result of interaction, except under unusual conditions (when conserving children view an adult model who provides nonconservation responses [Rosenthal & Zimmerman, 1972, 1978]), and then the regression is not stable (Ames & Murray, 1982; Robert & Charbonneau, 1977, 1978).

Researchers in the Vygotskian tradition, much like their Piagetian counterparts, argue that development is most likely to occur when two participants differ in terms of their initial level of competence about some skill or task, work collaboratively on it, and arrive at shared understanding. However, whereas Piaget stressed the virtues of peer interaction, Vygotsky argued that collaboration with a more competent partner, *whether adult or peer,* could be beneficial. Vygotsky, moreover, argued that the benefits of social interaction begin in infancy.

Most Vygotsky-inspired researchers who study cognitive effects of collaboration have dealt with adult-child interaction (Brown & Ferrara, 1985; McLane, 1987; Newman, Griffin, & Cole, 1989; Saxe, Gearhart, & Guberman, 1984; Tharp & Gallimore, 1988; Valsiner, 1984, 1987; Wertsch, 1979; Wertsch & Hickmann, 1987; Wood, 1988), although a few scholars have examined peer interaction, either in comparison with adult-child interaction (Ellis & Rogoff, 1982, 1986; Gauvain & Rogoff, 1989) or in its own right (Forman & Cazden, 1985; Forman & McPhail, in press).

There are two key concepts for researchers who utilize a Vygotskian perspective. The first is the "zone of proximal development"; for collaboration to lead to development, interactions should be within the less competent partner's zone of proximal development. The second key concept is that of intersubjectivity, or the process whereby two participants in a task who begin with different understandings of it arrive at shared understanding in the course of communication.

Vygotsky defined the zone of proximal development as that area of development into which a child can be led in the course of interaction with a more competent partner, either adult or peer. The zone of proximal development has been discussed at some length elsewhere (Cole, 1985; Moll, 1990; Rogoff & Wertsch, 1984; Valsiner, 1987; Valsiner & van der Veer, in press); suffice it to say that the zone is not some clear-cut space that exists independently of the process of joint activity itself. Rather, it is the difference between what the child can accomplish independently and what he or she can achieve in conjunction with another, more competent, person. The zone is thus something that is *created* in the course of social interaction: "We propose that an essential feature of learning is that it creates the zone of proximal development; that is, learning awakens a variety of developmental processes that are able to operate only when the child is interacting with people in his environment and in collaboration with his peers" (Vygotsky, 1978, p. 90).

The second concept that, from a Vygotskian perspective, is essential for understanding the processes and consequences of peer collaboration is intersubjectivity. As Behrend (1990) has pointed out, intersubjectivity has been defined in different ways by those using the term (Rogoff, 1990; Rommetveit, 1979, 1985; Trevarthen, 1979, 1980; Wertsch, 1985). My use of the term is based on the view that individuals come to a task, problem, or conversation with their own subjective ways of making sense of it. If they then discuss their differing viewpoints, shared understanding may be attained. As Rommetveit states it: "Communication aims at transcendence of the 'private' worlds of the participants. It sets up what we might call 'states of intersubjectivity'" (1979, p. 94). In other words, in the course of communication, participants may arrive at some mutually agreed-upon, or intersubjective, understanding.

Scholars working in the tradition of Vygotsky (like those influenced by Piaget) would argue that if partners already have the same understanding of a task (share the same subjective sense of it), the situation is little different from exploring the problem alone; development is less likely to occur than if they have different initial understandings. On the other hand, an initial difference in understanding may not lead to development if one partner simply agrees with the other with no attempt to understand the other's viewpoint-in which case intersubjectivity would not have been attained. Similarly, one would not expect development to occur if the gulf between the participants were too great to allow for shared understanding.

A critical element of Vygotsky's theory is that the more competent thinking or performance displayed by the child in the collaborative process itself should be internalized or "appropriated" (Leontyev, 1981; Rogoff, 1990) for use in subsequent individual performance. As Vygotsky wrote with reference to the results of interaction between a teacher and child, when the child subsequently solves a problem independently, "he continues to act in collaboration, even though the teacher is not standing near him .... This help—this aspect of collaboration—is invisibly present. It is contained in what looks from the outside like the child's independent solution of the problem" (Vygotsky, 1987, p. 216). In other words, the intersubjective understanding gained in the course of collaboration becomes the child's own (though socially derived) subjective understanding, an understanding that incorporates the shared understanding previously established.

With the exception of his discussion of the way in which a child, in the course of play, creates his or her own zone of proximal development (Vygotsky, 1978), Vygotsky only described interactions between adults and children, more specifically, teachers and children. Vygotsky declared that more competent peers may be effective in assisting a less competent child's development, but he did not discuss the impact of such collaboration on the more competent child's thinking. Of particular concern for researchers interested in peer collaboration is the fact that participants' relative degrees of competence (as judged by prior independent testing) may be less apparent to the partners than to the researcher, and the less competent partner might persuade the other of the correctness of his or her problem solution. Thus, arriving at a situation of shared meaning or intersubjectivity could have either deleterious or beneficial consequences, depending on whose initial understanding is accepted as correct.

The research to be described below focuses first on the consequences of collaborating with a partner assessed as being at the same competence level, with a more competent partner, with a less competent partner, or with no partner. However, as Vygotsky argued with regard to the higher forms of mental functioning, such as problem solving: "We need to concentrate not on the *product* of development but on the very *process* by which higher forms are established" (1978, p. 64). Therefore, the second focus of this paper is on the collaborative processes themselves, particularly those engendered by the dyads featuring different levels of competence, for it is here that shared understanding may be created from what were originally two different understandings.

Method

Subjects

The sample consisted of 162 children aged from 5 to 9, of whom nine were subsequently dropped. Of the 153 who participated further, 51 were in kindergarten classes (25 male, 26 female, *M* age = 66.6 months, SD = 3.9, range 60-72 months), 55 were in mixed first- and second-grade classes (26 male, 29 female, *M* = 82.9 months, SD = 8.7, range 72-100 months), and 47 were in mixed third- and fourth-grade classes (19 male, 28 female, *M* = 112.0 months, SD = 8.8, range 99-134 months). All participants were drawn from an open-enrollment public elementary school in Ithaca, New York, and consisted of a mix of social classes and race.

Materials

A mathematical balance beam was used, similar to that employed by Siegler in his extensive research on the development of rule-based thinking in children (Siegler, 1976, 1981). This task was used because each "rule" requires thinking that deals with the relevant variables in a more sophisticated way than lower rules, and because no children of the ages of interest were likely to be at ceiling.

The beam had eight removable sticks placed at equal distances from the central fulcrum, and was held stable by wooden blocks supporting it at both ends. The blocks were removable to allow the children to observe free movement of the beam at the start of the experiment, but thereafter remained in place. Metal nuts that fitted over the sticks were used as the weights in the pretest and two posttests. In the treatment, when the children were paired, the content of the task was similar but the form was different; the sticks were replaced by clear plastic beakers and the weights were replaced by identical plastic figures that were placed into the beakers. This was done so that the children would be less tempted to try to "remember" configurations they had seen in the previous session.

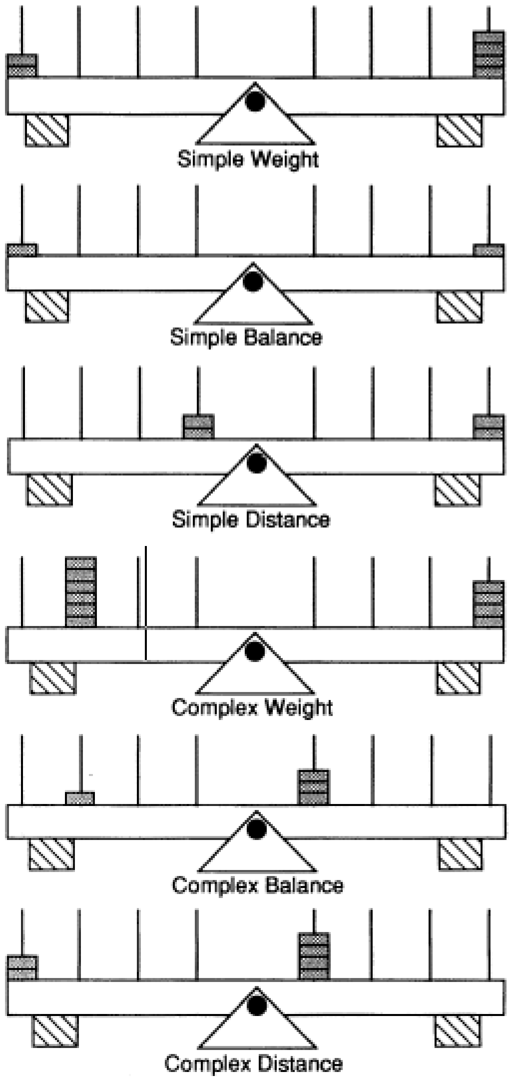

Figure 1. Examples from each of the six types of balance beam problems.

The actual configurations were taken, with minor variations, from those used by Siegler (1981), who used 24 problems, comprising four each of the six different "problem types" indicated in Figure 1. For the present study, 14 different problem configurations were used, including four simple distance problems and two of each of the remaining problem types. Half of Siegler's (1981) problems were used for the pretest and second posttest, the other half for the treatment (with two additional simple distance problems in each instance), and very similar problems were used for the first posttest. In each case, the weights were placed on only one stick on each side of the fulcrum, with a maximum of six weights on any one side and a maximum of 10 on both sticks.

Assignment to Rule

Siegler (1981) identified four basic rules (and one variant) that children use to predict the movement of a balance beam when different numbers of weights are placed at varying distances from the fulcrum. During pilot testing, however, it became obvious that finer degrees of differentiation were possible. Seven rules can reliably be identified, ranging from simple guesswork, with no consistent attempt to consider either number of weights or distances, to the ability to predict precisely what will happen when any configuration of weights is placed on the beam.

Rule 0.—No understanding either of the idea of balance or of what will happen when one side of the beam has more weights. Of the original 162 children who were tested, nine were dropped as they used Rule 0.

Rule 1 (Siegler's Rule I').—Children using this rule consistently predict that the side that has the greater number of weights will tip down (simple weight and all complex problems [see Fig. 1]), but inconsistently guess either one side or the other for problems with equal weights (simple balance and distance problems). Eleven children, mean age 72.9 months, range 62-107 months, used this rule.

Rule 2 (Siegler's Rule I).—Children using this rule consistently predict that the side that has the greater number of weights will tip, and that the remaining problems will balance. Fifty-two children, mean age 76.9 months, range 60-117 months, used this rule.

Rule 3 (Not described by Siegler).—Children using this rule consistently predict that the side with the greater number of weights will tip, and that the simple balance problems will balance. Their predictions about the four simple distance problems are inconsistent, however, with respect both to taking distance into account and (if considering distance) whether the beam will tip to the side furthest from or closest to the fulcrum. One or two predictions that simple distance problems would tip, justified with reference to distance, were sufficient to classify a child as using Rule 3 (assuming the remaining predictions reflected Rule 2 reasoning). Twenty-four children, mean age 83.2 months, range 61-119 months, used this rule.

Rule 4 (Siegler' s Rule II).—Children using this rule consistently predict that the side with the greater number of weights will tip, that the simple balance problems will balance, and that the simple distance problems will tip to the side furthest from the fulcrum. Children using this rule simultaneously consider the variables of number and distance when the numbers are equal but the distance is not. Thirty-five children, mean age 90.1 months, range 65-131 months, used this rule.

Rule 5 (Siegler's Rule III).—Children using this rule predict consistently (and correctly) for all the simple problems, but predict inconsistently for the complex problems. Children using this rule view distance as important even when the numbers of weights are different, but sometimes predict that the complex problems tip to the side with greater number, sometimes to the side with greater distance, and sometimes balance—and make their decision by guesswork. One or more predictions in which a child argued that distance was as or more important than numbers of weights on the complex problems was sufficient to classify that child as using Rule 5, assuming that the remaining predictions were appropriate to Rule 4. Thirty-one children, mean age 101.9 months, range 60-134 months, used this rule.

Rule 6 (Siegler's Rule IV).—This rule features an understanding of what will happen in each problem, gained by multiplying the number of weights by the distance from the fulcrum. All configurations can be consistently and correctly predicted. No children used this rule.

To ascertain which rule children used required examination of the entire pattern of predictions and justifications to all 14 problems. Siegler (1981) required that children predict appropriately for a minimum of 20 of 24 problems to be classified as using one rule or another. In this study, a minimum of 13 of 14 problems was used to classify a child; one prediction, at variance with the remaining pattern, was insufficient to move a child to the next lower rule. However (as mentioned above), one discrepant prediction was sufficient to move a child to the next higher rule, if that prediction was appropriately justified.

Procedure

Pretest.—Having spent several days in each classroom, the experimenter explained and demonstrated the working of the apparatus to each child, individually, after which the 14 problems were presented. The child was asked to predict whether the beam would stay balanced or tip one way or the other if the supports were removed (they never were removed), and to justify that prediction.

Treatment.—The treatment phase occurred a minimum of 2 days (maximum 12 days) after pretesting in each class (M = 3.87 days, SD = 1.37). Participants were assigned to one of three treatment conditions: (1) A control group, in which subjects had no partner, and were always tested individually *(n* = 41). (2) An "equal rule" group, in which each child was paired with another child who, at pretest, had used the same rule as he or she had (n = 38). For purposes of analysis, one member of each equal rule dyad was randomly dropped, to allow independence of the units of analysis (retained *n* = 19). (3) An "unequal rule" group, in which each child was paired with another child who, in the pretest, had used a different rule than he or she had *(n* = 74). For purposes of analysis, only one member of each dyad (either the less competent or more competent member, chosen at random) was retained. This process resulted in a group of less competent members *(n* = 19) and a group of more competent members (n = 18), all of whom were independent of each other.

Assignment to treatment condition was governed by the following constraints. Pairs were of the same gender and school class, and could be no more than two rules apart. Wherever possible, classmates were distributed so as to get equal numbers of individuals, equal rule children, less competent members, and more competent members. Within these constraints, and the fact that Rule 1 children could not be assigned to be higher partners and Rule 5 children could not be assigned to be lower partners, children using the same rule were randomly assigned to condition.

Members of pairs took turns to be the first to predict each configuration. After both had made their predictions, each child was asked, in turn, to justify his or her prediction. When their predictions conflicted, the children were asked to explain their reasons to one another and reach agreement on one prediction. At this point, the experimenter moved out of obvious earshot (to allow the children to discuss freely), returning when the children had reached agreement. No feedback was provided at any point, either from the materials or by the experimenter, who participated in all phases of the research.

Posttests.—The children were retested individually, to determine whether or not there had been any change in their rule use several days after the treatment (M = 2.68 days, SD = 2.22, range 2-9 days). A second posttest was given, to determine the stability of any changes that might have taken place, a minimum of 4 weeks after the first posttest (M = 32.65 days, SD = 4.12, range 28-47 days).

Each session (the pretest, treatment, and two posttests) was audiotaped, and the experimenter and a second coder (blind to the experimental hypotheses and to the treatment) independently determined which rule each child used in that session. This was determined by the pattern of predictions and the justifications for the 14 configurations. Interrater reliability of assignment to rule was 89.9% for the pretest (across all rules), 94.8% for the treatment, 96.3% for the first posttest, and 94.8% for the second posttest. Rules allowing consistent prediction were somewhat easier to code (97.7% agreement overall) than those incorporating some inconsistency (88.7% agreement overall, the lowest being 76.7% agreement for Rule 1). When there were disagreements, the protocols were rescored blind by both coders and discussed until disagreements were resolved.

A separate set of coders (blind as to the partners' pretest rules and type of pairing) coded (from both audiotapes and transcripts) the justifications used by each partner following the predictions and during any discussions. Justifications were of four types: no or idiosyncratic justification ("I like the blue side"); considering only number of weights, irrespective of distance from the fulcrum; considering distance when the number of weights was equal; and considering distance from the fulcrum when the number of weights was unequal. Interrater reliability of level of justification was 92% (disagreements were caused primarily by difficulties in hearing the children's responses, and were discussed until resolved in all but three cases, which were not used in these analyses).

Subsequently, three further variables were created. *Reasoning exposed to* was a measure of whether children were exposed by their partner to reasoning that was at the same level, lower, or higher than the reasoning associated with their pretest rule. Higher (or lower) reasoning exposed to was indicated by a partner's verbal justification in support of a prediction in which both the prediction and justification were appropriate to a rule higher (or lower) than that used by the target child during the pretest. The justification could be made either immediately after the initial predictions or during the discussion that followed a disagreement on predictions. Thus, if both partners of an unequal rule pair initially predicted and justified using reasoning appropriate to their pretest rules, the more competent partner was coded as being exposed to lower reasoning, the less competent partner coded as being exposed to higher level reasoning.

Reasoning adopted was a measure of whether children continued to use predictions and justifications appropriate to the pretest rule throughout (i.e., adopting the same reasoning), or adopted lower or higher level predicting and reasoning. It was possible for children to adopt lower or higher reasoning without having been exposed to it by their partner by justifying at a higher or lower level prior to their partner using that reasoning. For children to be coded as having adopted reasoning different from their pretest, they had to clearly predict and justify those predictions using reasoning appropriate to a rule other than their pretest rule. All paired sessions were independently coded for reasoning exposed to and reasoning adopted; interrater reliability was 91.9% for the former and 88.2% for the latter, with no decision reachable on three subjects.

Reasoning accepted was defined as agreement between reasoning exposed to and reasoning adopted, under the condition that this reasoning differed from that used at the pretest. It was thus a measure of whether children were exposed to, and subsequently adopted, reasoning either higher or lower than that associated with their pretest rule. Occasionally children simply gave way to their partner without accepting the reasoning (wanting to go on to the next problem, or deciding it would be futile to try to convince the partner), in which case they were coded as having neither adopted nor accepted the partner's reasoning. Children were thus classified either as "acceptors" of their partner's reasoning (if they had been exposed to and had adopted such reasoning) or as "nonacceptors."

Results

CONSEQUENCES OF COLLABORATION

Initially, I shall focus on the consequences (rather than the processes) of collaboration. To examine whether the random exclusion of one member of each dyad may have unexpectedly affected the results, identical analyses were conducted with the entire sample. There were virtually no differences in the pattern of significant and nonsignificant findings. Moreover, analysis of all pair members using Inclusion/Exclusion as a variable revealed no significant differences between pair members who had been excluded and those included in the analyses discussed below.

A 4 (condition: individuals, equal rule pairs, less competent partners, more competent partners) × 2 (gender) × 3 (age group: 5-year-olds, 6-7-year-olds, 8-9-year-olds) × 4 (time: pretest, treatment, posttest 1, posttest 2) multivariate analysis of variance (MANOVA) was conducted, using a multivariate approach to the analysis of repeated measures data (Maxwell & Delaney, 1990). The first three factors were between-subjects factors, the fourth within-subjects. The General Linear Model of SAS (SAS, 1989) was used to allow for unequal cell sizes. Four subjects were unavailable for the second posttest; these analyses were therefore conducted with 93 subjects.

The MANOVA revealed that the main effect of time was not significant, and of the interactions, only the time × condition and time × gender effects proved significant. All other interactions were therefore dropped from the model. Age group was retained in the model because of significant between-subjects effects (to be discussed later). The results reported here refer to the *independent* effects of each of the variables (condition, gender, and age group), controlling for all other variables.

The Effect of Treatment Condition on Outcome

Between-subjects effects revealed no significant effect of condition, F(3, 86) = 2.04, N.S., indicating that the different conditions did not differ in terms of their overall mean level of rule use. MANOVA revealed that time, as a main effect, was not significant (Wilks's lambda F(3, 84) = 0.63, N.S.), but that the interaction of time × condition was significant (Wilks's lambda F(9, 204) = 4.03, $p < .0001$). Planned comparisons of condition × time revealed that the four conditions at time 1 (pretest) significantly differed from those at time 2 (treatment), time 3 (first posttest), and time 4 (second posttest) (all *df's* 3, 86, F's > 8.38, *p's* < .0001), but that no other comparison was significant (i.e., conditions at time 2 did not differ from those at times 3 and 4, and so on). In other words, and as revealed in Table 1, the treatment conditions had a powerful impact on children's performance, and changes effected during the paired session proved highly stable. For this reason, discussion of the findings will focus on the second, delayed, posttest.

Table 1. Mean Rule Use at Pretest, Treatment, and Two Posttests, by Treatment Group

		Pretest		Treatment		First Post		Second Post	
Group	***N***	***M***	**(SD)**	***M***	**(SD)**	***M***	**(SD)**	***M***	**(SD)**
No partner	38[a]	3.00	(1.38)	2.92	(1.46)	2.89	(1.48)	3.00	(1.49)
Equal partners	19	3.16	(1.38)	2.95	(1.51)	2.89	(1.29)	2.79	(1.55)
Less competent partners	19	2.42	(.90)	3.26	(1.24)	3.11	(1.24)	3.11	(1.24(
More competent partners	17[b]	4.29	(.85)	3.47	(1.37)	3.53	(1.23)	3.65	(1.22)

[a] Three additional non paired children completed all but the second posttest.

[b] One additional more competent partner completed all but the second posttest.

The data were converted to difference scores (posttest-pretest) and analyzed by univariate 4 (condition) × 2 (gender) × 3 (age group) analyses of covariance (ANCOVA) run on the difference scores, with pretest score as the covariate. All factors were between-subject factors. The data presented here and in subsequent analyses relate to the differences between the second posttest and the pretest. (Identical analyses were conducted on the first posttest-pretest difference scores, but these findings will be reported only when they did not parallel the findings based on second posttest-pretest differences.) The analyses revealed that the type of pairing explained a significant (and independent) amount of the variance, F(3, 85) = 4.63, $p < .005$. Post hoc tests of all pair-wise comparisons (using Tukey's HSD) revealed that the less competent partner condition differed significantly ($p < .05$) from each other condition, and that the more competent partner condition differed from the nonpaired condition ($p < .05$). No other comparisons were significant. Two-tailed *t* tests for dependent samples were run on the second posttest-pretest gains (or losses), comparing them with zero (no change). These analyses revealed that the group of less competent children was the only group that improved significantly from pretest score (M = 0.68, SD = 0.89, t(l8) = 3.37, $p < .005$). The group of more competent children was the only group to decline significantly (M = -0.65, SD = 1.06, t(l6) = - 2.52, $p < .03$). Children in the equal rule group declined, but not significantly (M = -0.37, SD = 0.83, t(l8) = -1.93, $p < .07$), and the nonpaired children on average used the same rule (M = 0, SD = 0.90).

Regression artifacts.—Some of this change from one rule to another may be attributable to regression artifacts-more competent members had, on average, necessarily used a higher rule at the time of the pretest, while less competent members had used a lower rule. There are two ways in which regression artifacts must be considered here-the relative level (within the dyad) and the absolute level of the rules. First, focusing on the relative difference between members of unequal rule dyads, it should be noted that the more competent members of dyads did not exclusively use the highest rules. A Rule 2 user, paired with a child who used Rule 1, would be a more competent member; a Rule 2 user, paired with a child who used Rule 3, would be a less competent member. Irrespective of how high or low their initial scores were, less competent members tended either to improve on their pretest scores or continue to use the same rule, whereas more competent members tended either to regress or use the same rule. Moreover, regression artifacts would suggest that compromise would feature prominently in those dyads whose members differed by two rules. In fact, of the 17 dyads in which compromise was a possibility, this only occurred for two of them.

Second, focusing on the absolute level of the rules, regression artifacts would result in Rule 1 nonpaired children improving as much as Rule l less competent partners, and in Rule 5 nonpaired children declining as much as Rule 5 more competent partners. This hypothesis was not supported in the case of the Rule 1 children; all five nonpaired children continued to use their pretest scores at the time of the second posttest, whereas both less competent children improved by one rule. However, Rule 5 children did not significantly differ; four of the eight children who were not paired declined, as did three of the eight more competent partners. This finding may be evidence in favor of the regression hypothesis; an alternative hypothesis is that inconsistency is an uncomfortable cognitive state (Festinger, 1957), and it may be easier to slip down to a less sophisticated rule that allows consistency than to continue to use an inconsistent rule. Support for this hypothesis is derived from the fact that, whereas five of the seven nonpaired Rule 3 children declined to Rule 2, none of the eight nonpaired Rule 4 children declined, a pattern difficult to attribute to regression artifacts.

Third, regression artifacts should be strongest for children using either Rule 1 or Rule 5 at the pretest. However, ANCOVAs run (with those children excluded) on condition and gender, with the dependent variable being the second posttest-pretest difference scores and pretest acting as the covariate (age group no longer exerted a significant effect), revealed, as before, a significant main effect of condition, $F(3, 58) = 3.59$, $p < .02$. Post hoc comparisons (using Tukey's HSD) for all pair-wise comparisons revealed that the only significant ($p < .05$) comparison was between the lower partner and higher partner conditions. As was the case with the larger sample, two-tailed *t* tests for dependent samples run on the second posttest-pretest differences revealed that only the group of less competent partners improved significantly ($M = 0.65$, $SD = 0.93$, $t(16) = 2.86$, $p < .02$); the group of more competent partners did not decline significantly at the time of the second posttest ($M = -0.56$, $SD = 1.01$, $t(8) = -1.64$, $p < .15$), although it did so at the first posttest ($M = - 0.89$, $SD = 1.05$, $t(8) = - 2.53$, $p < .04$).

The Effect of Gender on Outcome

With the exception of Bearison and his colleagues (Bearison & Filardo, 1986; Bearison, Magzamen, & Filardo, 1986), scholars who have examined the effects of peer collaboration on cognitive development either have not found or have not reported different types of performance for boys and girls. In the present study, the repeated-measures analysis revealed no between-subjects effects, F(l, 86) = 1.45, N.S., indicating that on average boys and girls did not differ in terms of their overall rule use. However, the MANOV A time x gender interaction was significant (Wilks's lambda F(3, 84) = 3.48, $p < .02$). Planned comparisons across times for each gender revealed that the rules used by boys and girls at time 1 (pretest) differed significantly from their rule use at times 2, 3, and 4 (all *df*'s 1, 86, F's> 4.33, *p*'s < .05), but that no other comparison was significant.

Subsequent univariate ANCOVAs (examining the independent effects of gender on second posttest-pretest difference scores in a model that included condition and age group, with pretest score as the covariate) revealed that boys and girls differed significantly across all conditions, F(l, 85) = 7.62, $p < .008$. Analysis of the second posttest-pretest differences by two-tailed *t* tests for dependent samples revealed that boys (pretest $M = 3.04$, SD = 1.36) did not significantly improve on their pretest rule (M = .21, SD = 0.87, t(42) = 1.30, $p > .2$), whereas girls (pretest M= 3.23, SD = 1.29) significantly declined from their pretest rule (M= -.28, SD = 0.90, t(49) = -2.19, $p < . 05$). As previously noted, the interaction of condition × gender was not significant; the pattern of improvements across types of pairing was essentially the same for boys and girls.

The Effect of Age on Outcome

The repeated-measures MANOVA revealed a significant between-subjects effect of age, F(2, 86) = 20.27, $p < .0001$, indicating that the three age groups differed greatly in their overall mean level of rule use. The MANOVA test of the time × age group interaction revealed, however, that the pattern of differences between the age groups did not differ significantly over time (Wilks's lambda F(6, 168) = 1.34, N.S.). Post hoc tests of all pair-wise comparisons (using Tukey's HSD) revealed that at all four times all age groups differed significantly ($p < .05$) from each other in terms of rule use. At the pretest, for example, although children at each age level used the full range of rules, the 5-year-olds used a lower rule on average (M = 2.38, SD = 1.16) than the 6-7-year-olds (M = 3.19, SD = 1.14), whereas the 8-9-year-olds used, on average, higher rules (M = 3.93, SD = 1.22). During treatment and at both posttests the ordering of age group relative to rule use remained the same.

Because the between-group differences were significant, age group was kept in the ANCOVA model analyzing second posttest-pretest difference scores (pretest being the covariate), which revealed that the 5-yearolds, 6-7-year-olds, and 8-9-year-olds significantly differed in terms of second posttest performance, F(2, 85) = 5.87, $p < .005$. However, post hoc tests of all pair-wise comparisons (using Tukey's HSD) revealed no significant differences between any pairs of age groups in terms of improvement or decline. Two-tailed *t* tests for dependent samples on the second posttest-pretest differences revealed that across conditions the 5-year-olds and the group of 6-7-year-olds both declined from pretest, though not significantly (M's = -0.19, SD = 0.98 and -0.12, SD = 1.20, respectively), whereas the 8-9-year-olds improved (M = 0.18, SD = 0.72), though not significantly.

Most noteworthy, the age × condition interaction was not significant, indicating that the effects of being paired with a more or less competent partner did not vary by age; 5-year-olds paired with a more competent peer were as likely to benefit from collaboration as 8-9-year-olds, and children of each age group were as likely to decline when paired with a less competent child.

PROCESSES OF INTERACTION

The analyses presented so far reveal that the presence and type of partner had a profound impact on both development and regression. To understand the reasons for both, it is necessary to examine the collaborative processes themselves to ascertain what occurred during the treatment session. Accordingly, the unit of analysis must change, from the individual to the dyad, in order to retain independence of the units. The outcome measure will therefore be dyadic, but rather than be a simple aggregate of the individual members' scores will comprise a measure of outcome patterns. Of the possible dyadic outcomes, all but two of the 56 dyads fell into one of three patterns: one or both pair members declined, with the other member at best retaining the pretest rule; both partners retained the same rule; one or both pair members improved, with the other member at worst retaining the pretest rule. (The partners in the two remaining dyads compromised, and were not included in the following analyses.)

Type of Partner

Dyads featuring children who came to the task with the same initial understanding (equal rule dyads) differed from unequal rule dyads in their pattern of rule retention, declines, and improvements, $\chi^2(2, N = 54) = 18.15$, $p < .0001$. Post hoc analyses were conducted first to discover whether the dyads significantly differed in terms of retention or changing their pretest rules, and second to discover, in the case of those who changed rules, whether the change was to a higher or a lower rule. These analyses (all of which were two-tailed) revealed that equal rule dyads were significantly more likely than unequal rule dyads to retain the same rule than change (nine of 19 and one of 35, respectively, Fisher's Exact Test, $N = 54$, $p < .0001$). However, among equal and unequal rule dyads in which rule change occurred, the direction of change did not differ significantly (Fisher's Exact Test, $N = 44$, $p > .15$).

When regression occurred, it was more likely for both members of equal rule dyads to decline (four of seven dyads) than was the case for members of unequal rule dyads (one of 14 dyads), where the less competent child tended to retain the same rule and the more competent partner tended to move down (Fisher's Exact Test, $N = 21$, $p < .001$). The same was true of improvement—when this occurred in equal rule dyads it was true of both members (in all three cases), whereas in unequal rule dyads the more competent member typically (17 of 20 cases) retained his or her pretest rule, while the less competent child improved (Fisher's Exact Test, $N = 23$, $p < .02$).

Partners' rule relations.—Unequal rule partners were more likely to change rules than equal rule partners, and improvement was as likely as decline. But what induced dyad members to improve or decline? An understanding of partners' rule relations provides some answers. As described earlier, Rules 1, 3, and 5 incorporate inconsistency of response to some problems, whereas Rules 2 and 4 do not.

It should be noted initially that some of the dyads differed by two rules (partners both used either inconsistent rules [Rule 5-3 dyads] or consistent [Rule 4-2 dyads]), some by only one, but analysis revealed no significant differences in terms of either improvement or regression

(Fisher's Exact Test, $N = 34$, $p = .30$). (The one dyad featuring children who retained their pretest rules [a high inconsistent-low consistent dyad] was dropped from this and subsequent analyses.)

Examining first *equal rule dyads,* children in six of the eight "same inconsistent rule" dyads (five Rule 5, two Rule 3, and one Rule 1) changed rules, compared to only four of the 11 "same consistent rule" dyads (eight Rule 2 and three Rule 4 dyads). This difference, while suggestive, was not significant, however (Fisher's Exact Test, $N = 19$, $p > .16$). (A similar pattern was found among nonpaired children; 11 of 20 children using an inconsistent rule changed rules, compared to only seven of 21 who used a consistent rule, but this difference was not significant [Fisher's Exact Test, $N = 41$, $p > .2$].)

Among *unequal rule dyads,* the patterns proved to be very different. These partners arrived at the collaborative session with different understandings of the task, and thus with the opportunity to arrive at a shared understanding-an understanding that could be, at least for the less competent partners, an opportunity for arriving at shared meaning at a higher level.

The unequal rule dyads can be divided into four different types, based on partners' competence (high vs. low) and rule (consistent vs. inconsistent): *(a)* high consistent—low inconsistent dyads (two Rule 4-Rule 3 and four Rule 2–Rule 1 dyads), *(b)* high inconsistent-low consistent dyads (seven Rule 5–Rule 4 and five Rule 3–Rule 2 dyads), *(c)* different rules, both inconsistent (five Rule 5–Rule 3 dyads), and *(d)* different rules, both consistent (12 Rule 4–Rule 2 dyads).

The most important comparison was between the high consistent-low inconsistent dyads and the remaining dyads, for the former are the analogs of the conserver-nonconserver dyads examined by the neo-Piagetian scholars. As can be seen in Table 2, these dyads were significantly more likely to feature improvement (in five of the six cases the less competent child improved while the more competent child retained the pretest rule, and in the sixth case both partners improved) than all other dyads, half of which featured decline and half improvement, with the one dyad in which the partners retained their pretest rules dropped from this analysis (Fisher's Exact Test, $N = 34$, $p < .05$).

Table 2. Numbers (and %) of Dyads in Which Decline, Retention of Rule, and Improvement Occurred, Related to Consistency/Inconsistency of Partners' Rules in Equal and Unequal Rule Dyads

Rule Relationship[a]	Both Down		One Down[b] One Stays		Both Stay		One Up[c] One Stays		Both Up	
Equal rule dyads:										
Both C[d] (2-2, 4-4)	1	(9.1)	1	(9.1)	7	(63.6)	0	(0)	2	(18.2)
Both Inc[d] (1-1, 3-3, 5-5)	4	(50.0)	1	(12.5)	2	(25.0)	0	(0)	1	(12.5)
Unequal rule dyads:										
High C-low Inc (4-3, 2-1)	0	(0)	0	(0)	0	(0)	5	(83.5)	1	(16.7)
High Inc-low C (5-4, 3-2)	0	(0)	5	(41.7)	1	(8.3)	6	(50.0)	0	(0)
Diff Inc (5-3)	1	(20.0)	1	(20.0)	0	(0)	3	(60.0)	0	(0)
Diff C (4-2)	0	(0)	7	(58.3)	0	(0)	3	(25.0)	2	(16.7)

[a] The five most common dyadic outcomes (two unequal dyads compromised).
[b] In unequal rule dyads, the higher partner declined.
[c] In unequal rule dyads, the lower partner improved.
[d] C = consistent rule at pretest; Inc = inconsistent rule at pretest.

Thus only the collaboration between high consistent–low inconsistent partners was an unqualified success, in that the lower (less competent) partners all improved, whereas no higher (more competent) partners regressed. In the three remaining dyadic types, the patterns of improvement and regression of one or both partners were far more variable.

Attaining Intersubjectivity

What might account for the fact that members of dyads that were identical in terms of type of partner and rule relations differed so clearly during the paired sessions? One possible answer relates to the intersubjective understanding attained in each dyad. As described above, reasoning accepted was defined as agreement between reasoning exposed to and reasoning adopted, under the condition that this reasoning differed from that used at the pretest. Acceptors were fairly evenly distributed by age group (seven of 12 5-year-olds, nine of 13 6–7-year-olds, and three of 11 8–9-yearolds accepted their partner's reasoning) and by gender (eight of 16 boys and 11 of 20 girls accepted their partner's reasoning).

To test the extent to which accepting the partner's reasoning had an effect on posttest scores, a 2 (reasoning accepted: yes, no) × 2 (condition: less competent dyad members, more competent dyad members) × 2 (gender: male, female) × 3 (age group: 5-year-olds, 6–7-year-olds, 8–9-year-olds) × 2 (consistency; consistent rule, inconsistent rule) analysis of covariance (ANCOVA) was run on the second posttest-pretest difference scores, with pretest score as the covariate. Gender, age group, and consistency did not exert significant independent effects on the posttest, either as main effects or in interaction with reasoning accepted, and were therefore dropped. This analysis revealed that although reasoning accepted as a main effect did not account significantly for posttest performance, $F(1, 31) = 1.38$, $p > .2$, both the main effect of condition, $F(1, 31) = 6.41$, $p < .02$, and the interaction of reasoning accepted and condition, $F(1, 31) = 20.48$, $p < .0001$, were significant. To clarify the nature of the two-way interaction, ANCOVAs were run to test the simple effects of reasoning accepted on each condition separately. Reasoning accepted was significantly related to second posttest performance for the group of less competent dyad members, $F(1, 16) = 5.57$, $p < .04$, and the group of more competent dyad members, $F(1, 14) = 17.42$, $p < .001$.

Two-tailed *t* tests for dependent samples run on the second posttest-pretest differences revealed that, on average, acceptors (M = - 0.05, SD = 1.54, $n = 19$) and nonacceptors (M = 0.18, SD = 0.53, $n = 17$) did not significantly improve or decline from pretest. On the other hand, the group of less competent dyad members significantly improved from pretest (M = 0.68, SD = 0.89, $t(18)=3.37$, $p < .004$), and the group of more competent dyad members significantly declined (M = -0.65, SD = 1.06, $t(16) = -2.52$, $p < .03$). The pretest rule used by the less competent members (M = 2.42, SD = 0.90, $n = 19$) was on average lower than that used by the more competent members (M = 4.29, SD = 0.85, $n = 17$). These data appear to suggest that regression artifacts may have played a critical role in these results. However, the significant interaction of reasoning accepted and condition revealed that improvement among the less competent dyad members was found only for those who accepted their partners' reasoning, and that the same was true for declines of the more competent dyad members (see Table 3).

Table 3. Mean Improvements and Declines from Pretest to Delayed Posttest, as a Function of Condition and Accepting Partner's Reasoning

		Pretest Rule		Improvement and Decline			
Condition/Acceptance	***N***	***M***	**SD**	***M***	**SD**	***t*[a]**	***p***
Less competent:							
Acceptors	10	2.40	.97	1.10	.87	3.97	< .004
Nonacceptors	9	2.44	.88	.22	.66	1.00	< .4
More competent:							
Acceptors	9	4.22	.67	–1.33	1.00	–4.00	< .004
Nonacceptors	8	4.37	1.06	.12	.35	1.00	< .4

[a] Two-tailed *t* test for dependent samples, comparing the delayed posttest-pretest difference to zero (no change from pretest).

Discussion

Most of the developmental research on peer collaboration, primarily based on a Piagetian theoretical foundation, has supported the view that such collaboration leads to cognitive development. Less work has been conducted in this area by Vygotskian scholars, and the results (see, e.g., Forman & Cazden, 1985) are not so favorable. However, none of the previous research has provided evidence that the effects of collaboration can be detrimental to children's thinking. Indeed, as far as Piagetian scholars are concerned, regression should rarely occur, and at worst be short-lived.

In the current study, however, although collaboration between children who differed in their level of competence on occasion proved beneficial, regression was at least as common an outcome, and was just as stable. Part of the discrepancy in experimental outcomes may be traced to an unanticipated confound in the Piagetian-inspired research, which may have led to an overly optimistic portrayal of the cognitive consequences of collaboration. Most of the Piaget-inspired research features conserver-nonconserver pairs. The unintended confound is that conservers are necessarily (according to Piaget) more certain of their beliefs than nonconservers; only the former understand the "logical necessity" of their position (Murray, 1982, 1987; Smith & Murray, 1985; Tudge & Winterhoff, 1991). Additional research supports the view that this greater certainty (rather than social dominance, for example), is the key factor (Miller, 1986; Miller & Brownell, 1975; Miller, Brownell, & Zukier, 1977).

Results from studies featuring pairs of nonconservers or transitional conserver-nonconserver dyads may appear to run counter to this view. However, these data are inconclusive; in some studies nonconserver-nonconserver dyads benefited from collaboration (Ames & Murray, 1982; Mugny & Doise, 1978), but in other studies they did not (Mugny & Doise, 1978; Perret-Clermont, 1980; Russell, 1982). The same discrepancies are apparent among dyads featuring pairs of transitional conservers (Perret-Clermont, 1980). Smith and Murray (1985) argued that this difference in findings may be explained by differences in nonconservers' beliefs; some nonconservers in their study exhibited an erroneous "false necessity," and it was these children who improved. Other nonconservers, who had no such certainty in their beliefs, did not improve.

The present study allowed some disentangling of this confounding of competence and confidence, by pairing dyads in such a way that the more competent dyad members did not always have access to a rule that allowed consistency of prediction and thus, perhaps, more confidence in that rule. In line with the results reported both by Piagetian scholars and those influenced by Vygotsky, less competent inconsistent dyad members who were paired with more competent consistent partners clearly improved in their thinking, and the latter did not regress. However, this was the only condition that produced such favorable results; in many other cases improvement did not occur and some children regressed in their thinking. It seems clear that we must specify the conditions relating collaboration and development more carefully than has previously been done.

In this study, a reliance solely on the consequences of collaboration was insufficient to examine these conditions. The results indicated that, on average, the group of less competent partners improved as a result of collaboration whereas the group of more competent partners regressed. (Nonpaired children and those whose partner had used the same rule did not change much from pretest.) Focusing on the processes of collaboration, however, allowed fuller understanding of the conditions likely to lead to development, regression, or to no change in thinking.

For children to benefit from collaboration it appeared helpful to have a partner whose thinking was at a more advanced level, but this, by itself, was not sufficient; the more competent partner needed to introduce reasoning into the discussion at a level appropriate to his or her thinking. Of yet more importance was that the less competent child needed to accept that higher level reasoning (rather than simply being exposed to it) in the course of discussion.

As far as age differences are concerned, these results do not support a Piagetian interpretation, for 5-year-olds were as likely to benefit from collaboration (under the right conditions) as 8–9-year-olds. As Vygotsky argued, collaboration between a young child and a more competent peer can be an effective source of cognitive development. The gender differences that were found were not expected, however, and without further research any conclusions drawn from this study should be both tentative and speculative. It is possible, however, that because the task was mathematical or scientific it was of more interest to boys than to girls, and that the greater improvement on the part of boys is attributable to that greater interest. (It was not the case that boys were more likely to have access to a consistent rule than girls—no differences were found on that dimension—$\chi^2(1, N = 97) = 0.15, p > .6$.)

The current data, I believe, can best be understood within a Vygotskian framework. The study was not intended to be a test of Vygotsky's concept of the zone of proximal development—work is currently under way that examines the impact of the partner providing information at a variety of levels. Suffice it to say that, as expected, a zone of proximal development could be created in the course of discussion when the differences in rules were either one or two; no differences were found as a function of level. However, rather than assuming that when a zone is created it is unfailingly in a developmentally appropriate direction, these data suggest that such a zone may be formed either in front of or behind a child's current level of thinking, depending on the information provided by the partner and whether or not this reasoning was accepted. As is clear from the data provided in Table 3, regression of the more competent members of dyads and improvement of the less competent members seem to be a function of whether or not these children were persuaded to accept their partner's reasoning. Both members of a dyad thus attained intersubjectivity or shared understanding, but this process could lead either to developmental advance or decline. Vygotsky argued that "the zone of proximal development defines those functions that have not yet matured but are in process of maturation, functions that will mature tomorrow but are currently in embryonic state" (Vygotsky, 1978, p. 86). Perhaps functions (or approaches to problem solution) that are not fully developed are malleable and can have their development impeded, as a result of social interaction, leading to regression to a previously "developed" function, just as they can be raised to a developmentally more advanced level. (A similar point has been argued by Ignjatovic-Savic, Kovac-Cerovic, Plut, & Pesikan, 1988.)

There is little indication that agreement attained during the treatment was reached simply for the sake of agreeing; if so, as in the case of the conservers who "regressed" when paired with an adult who provided nonconservation responses (Ames & Murray, 1982), the regression should have been short-lived. Instead, changes in rule use that resulted from the process of discussion proved remarkably stable—whether they featured improvement or regression. In the cases where partners initially differed in their thinking, what occurred during the treatment was more than just agreement, therefore; shared understanding was attained by the pair members and intersubjectivity was reached. This newly found shared reasoning proved enduring. It was as though, as Vygotsky argued, the child's partner remained "invisibly present."

Some caution in generalizing should be exercised, however. First, the children in this study at no time received any feedback, either from the experimenter or from the materials themselves. As is the case with the Piagetian work with conservers and nonconservers, the children at no time received independent confirmation or disconfirmation of their predictions. Differences of opinion were resolved solely on the verbal plane. Thus the regression found in this study may be limited to situations in which children are not provided with any type of feedback. Support for this view is provided by research in which children, provided with feedback after working on similar problems, showed no evidence of regression (Tudge, 1991).

A second cautionary note is that the social world, which here has been instantiated as the dyadic interactions, also included a third person—the experimenter. The experimenter's role was simply to set up the problems, and see that the partners took turns to make their initial predictions. Once agreement was reached, no indication was given of the accuracy of that prediction. However, silence on the part of an adult typically implies consent—or surely an incorrect answer would be challenged. One reason for the stability in changes of rule use, once agreement was reached, may thus have been an inadvertent strengthening of the child's conviction that the agreed-upon prediction was correct.

Conclusion

The results of this research suggest that children can and do assist each other's thinking in the course of collaborative problem solving, as predicted by both Piagetian and Vygotskian theory. However, in contradiction to the typically beneficial results reported (particularly by Piagetian scholars), these data indicate that there are circumstances in which children can adversely affect each other's thinking. In this paper I have explored some of the conditions that need to be considered when children are asked to work together to solve problems and are not provided with feedback.

The results suggest that the Piagetian scholars working in this area (who also do not provide participants with independent confirmation or disconfirmation of their positions) may have overemphasized the benefits of collaboration by confounding competence and confidence. This study provided some support for the Vygotskian position, in that less competent children (including those younger than Piaget suggested) could indeed benefit from working with a more competent peer and that arriving at shared meaning or intersubjective understanding in the course of discussion was a highly effective means of bringing about changes in thinking. Working with a partner with whom there was already intersubjectivity was much less likely to be associated with change. On the other hand, the intersubjective understanding attained in the course of discussion was as likely to be in a regressive as in a progressive direction, with both regression (at least in the absence of disconfirming evidence) and development proving stable phenomena. This finding is certainly not predicted by Piagetian theory. It also does not fit with a Vygotskian position that incorporates the view that intersubjective understanding gained in collaboration with a more competent partner is always in a developmentally advanced direction. If these results prove to be replicable, it would imply that both Piagetian and Vygotskian theory (insofar as they relate to peer collaboration) may need to be amended.

References

Ames, G. J., & Murray, F. B. (1982). When two wrongs make a right: Promoting cognitive change by social conflict. *Developmental Psychology,* **18,** 894-897.

Azmitia, M., & Perlmutter, M. (1989). Social influences on children's cognition: State of the art and future directions. In H. W. Reese (Ed.), *Advances in child development and behavior* (Vol. **22,** pp. 89-144). New York: Academic Press.

Bearison, D. J., & Filardo, E. K. (1986). *Gender differences in children's dyadic interactions.* Unpublished manuscript, City University of New York.

Bearison, D. J., Magzamen, S., & Filardo, E. K. (1986). Socio-cognitive conflict and cognitive growth in young children. *Merrill-Palmer Quarterly,* **32**, 51- 72.

Behrend, S. D. (1990). *Understanding processes in children's collaborative problem solving.* Unpublished manuscript, University of Pittsburgh.

Brown, A. L., & Ferrara, R. A. (1985). Diagnosing zones of proximal development. In J. V. Wertsch (Ed.), *Culture, communication and cognition: Vygotskian perspectives* (pp. 273-305). Cambridge: Cambridge University Press.

Cole, M. (1985). The zone of proximal development: Where culture and cognition create each other. In J. V. Wertsch (Ed.), *Culture, communication and cognition: Vygotskian perspectives* (pp. 146-161). Cambridge: Cambridge University Press.

Doise, W., & Mugny, G. (1984). *The social development of the intellect.* Oxford: Pergamon.

Ellis, S., & Rogoff, B. (1982). The strategies and efficacy of child versus adult teachers. *Child Development,* **53,** 730-735.

Ellis, S., & Rogoff, B. (1986). Problem solving in children's management of instruction. In E. C. Mueller & C. R. Cooper (Eds.), *Process and outcome in peer relationships* (pp. 301-325). Orlando, FL: Academic Press.

Festinger, L. (1957). *A theory of cognitive dissonance.* Evanston, IL: Row, Peterson.

Forman, E. A., & Cazden, C. B. (1985). Exploring Vygotskian perspectives in education: The cognitive value of peer interaction. In J. V. Wertsch (Ed.), *Culture, communication and cognition: Vygotskian perspectives* (pp. 323-347). Cambridge: Cambridge University Press.

Forman, E. A., & McPhail, J. (in press). A Vygotskian perspective on children's collaborative problem-solving activities. In E. A. Forman, N. Minick, & C. A. Stone (Eds.), *Education and mind: The integration of institutional, social, and developmental processes.* New York: Oxford University Press.

Gauvain, M., & Rogoff, B. (1989). Collaborative problem solving and children's planning skills. *Developmental Psychology,* **29,** 139-151.

Ignjatovic-Savic, N., Kovac-Cerovic, T., Plut, D., & Pesikan, A. (1988). Social interaction in early childhood and its developmental effects. In J. Valsiner (Ed.), *Child development within culturally structured environments: Vol. 1. Parental cognition and adult-child interaction* (pp. 89-158). Norwood, NJ: Ablex.

Leontyev, A. N. (1981). *Problems of the development of mind.* Moscow: Progress Publishers.

Maxwell, S. E., & Delaney, H. D. (1990). *Designing experiments and analyzing data: A model comparison perspective.* Belmont, CA: Wadsworth.

McLane, J. B. (1987). Interaction, context, and the zone of proximal development. In M. Hickmann (Ed.), *Social and functional approaches to language and thought* (pp. 267-285). Orlando, FL: Academic Press.

Miller, S. (1986). Certainty and necessity in the understanding of Piagetian concepts. *Developmental Psychology,* **22,** 3-21.

Miller, S., & Brownell, C. (1975). Peers, persuasion, and Piaget: Dyadic interaction between conservers and nonconservers. *Child Development,* **46,** 992-997.

Miller, S., Brownell, C., & Zukier, H. (1977). Cognitive certainty in children: Effects of concept, developmental level, and method of assessment. *Developmental Psychology,* **13,** 236-243.

Moll, L. (1990). *Vygotsky and education.* Cambridge: Cambridge University Press.

Mugny, G., & Daise, W. (1978). Socio-cognitive conflict and structure of individual and collective performance. *European journal of Social Psychology,* **8**, 181-192.

Murray, F. B. (1982). Teaching through social conflict. *Contemporary Educational Psychology,* **7,** 257-271.

Murray, F. B. (1983). Learning and development through social interaction and conflict: A challenge to social learning theory. In L. S. Liben (Ed.), *Piaget and the foundations of knowledge* (pp. 231-247). Hillsdale, NJ: Erlbaum.

Murray, F. B. (1987). Necessity: The developmental component in school mathematics. In L. S. Liben (Ed.), *Development and learning: Conflict or congruence* (pp. 51-69). Hillsdale, NJ: Erlbaum.

Newman, D., Griffin, P., & Cole, M. (1989). *The construction zone: Working for cognitive change in school.* Cambridge: Cambridge University Press.

Perret-Clermont, A.-N. (1980). *Social interaction and cognitive development in children.* London: Academic Press.

Piaget, J. (1959). *The languge and thought of the child.* London: Routledge & Kegan Paul.

Piaget, J. (1977). *Etudes sociologiques* [Sociological studies]. Geneva: Librairie Droz.

Robert, M., & Charbonneau, C. (1977). Extinction of liquid conservation by observation: Effects of model's age and presence. *Child Development,* **48,** 648-652.

Robert, M., & Charbonneau, C. (1978). Extinction of liquid conservation by modeling: Three indicators of its artificiality. *Child Development,* **49,** 194-200.

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context.* Oxford: Oxford University Press.

Rogoff, B., & Wertsch, J. V. (Eds.). (1984). *Children's learning in the "zone of proximal development."* San Francisco: Jossey-Bass.

Rommetveit, R. (1979). On the architecture of intersubjectivity. In R. Rommetveit & R. M. Blakar (Eds.), *Studies of language, thought and verbal communication* (pp. 93-107). London: Academic Press.

Rommetveit, R. (1985). Language acquisition as increasing linguistic structuring of experience and symbolic behavior control. In J. V. Wertsch (Ed.), *Culture, communication and cognition: Vygotskian perspectives* (pp. 183-204). Cambridge: Cambridge University Press.

Rosenthal, T. L., & Zimmerman, B. J. (1972). Modeling by exemplification and instruction in training conservation. *Developmental Psychology,* 6, 392-401.

Rosenthal, T. L., & Zimmerman, B. J. (1978). So*cial learning and cognition.* New York: Academic Press.

Russell, J. (1982). Cognitive conflict, transmission, and justification: Conservation attainment through dyadic interaction. *Journal of Genetic Psychology,* **140,** 283-297.

SAS (1989). *SAS user's guide: Statistics.* Cary: SAS Institute.

Saxe, G. B., Gearhart, M., & Guberman, S. R. (1984). The social organization of early number development. In B. Rogoff & J. V. Wertsch (Eds.), *Children's learning in the "zone of proximal development"* (pp. 19-30). San Francisco: Jossey-Bass.

Siegler, R. S. (1976). Three aspects of cognitive development. *Cognitive Psychology,* **4,** 481-520.

Siegler, R. S. (1981). Developmental sequences within and between concepts. *Monographs of the Society for Research in Child Development,* **46(2,** Serial No. 189).

Smith, D. C., & Murray, F. B. (1985, June). *Necessity in nonconservers' reasoning.* Paper presented at the annual meeting of the Jean Piaget Society, Philadelphia.

Tharp, R. G., & Gallimore, R. (1988). *Rousing minds to life: Teaching, learning, and schooling in social context.* Cambridge: Cambridge University Press.

Trevarthen, C. (1979). Instincts for human understanding and for cultural cooperation: Their development in infancy. In M. von Cranach, K. Foppa, W. Lepenies, & D. Plooj (Eds.), *Human ethology* (pp. 530-571). Cambridge: Cambridge University Press.

Trevarthen, C. (1980). The foundations of intersubjectivity: Development of interpersonal and cooperative understanding in infants. In D. R. Olson (Ed.), *Social foundations of language and thought* (pp. 316-342). New York: Norton.

Tudge, J. R. H. (1991, April). *Feedback as a "zone of proximal development."* Paper presented at the biennial meetings of the Society for Research in Child Development, Seattle.

Tudge, J. R. H., & Rogoff, B. (1989). Peer influences on cognitive development: Piagetian and Vygotskian perspectives. In M. H. Bornstein & J. S. Bruner (Eds.), *Interaction in human development* (pp. 17-40). Hillsdale, NJ: Erlbaum.

Tudge, J. R.H., & Winterhoff, P. (1991, June). *The relationship between expertise and competence: Some implications for peer social interaction.* Paper presented at the annual meeting of the Jean Piaget Society, Philadelphia.

Tudge, J. R.H., & Winterhoff, P. (in press). Vygotsky, Piaget, and Bandura: Perspectives on the relations between the social world and cognitive development. *Human Development.*

Valsiner, J. (1984). Construction of the zone of proximal development in adult-child joint action: The socialization of meals. In B. Rogoff & J. V. Wertsch (Eds.), *Children's learning in the "zone of proximal development"* (pp. 65-76). San Francisco: Jossey-Bass.

Valsiner, J. (1987). *Culture and the development of children's action.* New York: Wiley.

Valsiner, J., & van der Veer, R. (in press). The encoding of distance: The concept of the "zone of proximal development" and its interpretations. In R. R. Cocking & K. A. Renninger (Eds.), *The development and meaning of psychological distance.* Hillsdale, NJ: Erlbaum.

Vygotsky, L. S. (1978). *Mind in society.* Cambridge, MA: Harvard University Press.

Vygotsky, L. S. (1987). *The collected works of L.* S. *Vygotsky: Vol. 1. Problems of general psychology.* New York: Plenum.

Wertsch, J. V. (1979). From social interaction to higher psychological processes: A clarification and application ofVygotsky's theory. *Human Development,* **22,** 1-22.

Wertsch, J. V. (1985). *Vygotsky and the social formation of mind.* Cambridge, MA: Harvard University Press.

Wertsch, J. V., & Hickmann, M. (1987). A microgenetic analysis of problem-solving in social interaction. In M. Hickmann (Ed.), *Social and functional approaches to language and thought* (pp. 251-266). Orlando, FL: Academic Press.

Wood, D. (1988). *How children think and learn.* Oxford: Basil Blackwell.