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The Effect of Peer Collaboration on Children's Problem Solving Ability

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The Effect of Peer Collaboration on Children's Problem Solving Ability

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A report submitted in partial fulfilment of the requirements for the award of Bachelor of Arts (Psychology) Honours Faculty of Community Studies, Education and Social Science, Edith Cowan University.

October 2002

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The Effect of Peer Collaboration on Children's Problem Solving Ability

Peer collaboration is a commonly used learning strategy, perceived by educators as a valuable educational activity. Studies do indicate a performance output benefit for children working collaboratively compared to children working individually. However, the longer term cognitive benefits of collaboration appear to be limited by a number of factors. It is suggested that cognitive change following peer collaboration is limited to children working with a more cognitively competent peer (or one with a different perspective), active participation and reasoned communication. This paper considers elements of Piaget's and Vygotsky's cognitive development theories in an attempt to explain some of the processes underlying peer collaboration, that may lead to cognitive change. Studies grounded in a Piagetian framework support the view that it is the cognitive conflict arising from peer interaction that leads to cognitive change. However, researchers in the Vygotskian tradition argue that cognitive change is most likely to occur when a child collaborates with a more competent partner. It is contended that the two theories are not as mutually exclusive as they are often portrayed. It appears that an important component in both theories is that cognitive change results when the interaction exposes a participant to a different knowledge source, whether it be due to a conflicting perspective (as argued by Piagetians), or a higher level of expertise (as argued by Vygotskians).

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Submitted: October 2002

Declaration

I certify that this thesis does not incorporate, without acknowledgement, any material previously submitted for a degree or diploma in any institution of higher education and that, to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where due reference is made in the text.

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[1] This paper was prepared in accordance with the *Instructions for Authors* for the British Journal of Developmental Psychology. For additional details see Appendix F.

The Effect of Peer Collaboration on Children's Problem Solving

Collaborative learning, along with other types of peer-based, small group instruction, is a commonly used teaching strategy in many Western Australian classrooms. But how effective is this as a learning strategy? How should children be grouped? What factors are integral to the collaborative learning process? And, in what theoretical framework can the underlying cognitive processes of peer collaboration be best understood?

Peer based learning encompasses at least three different forms of interaction: peer tutoring, co-operative learning and peer collaboration (Damon & Phelps, 1989). Peer tutoring involves the unidirectional transmission of knowledge from a more competent or expert child to a comparatively novice peer. Co-operative learning consists of small groups of children who each take individual responsibility for completing components of the total group workload. Peer collaboration involves children working together to complete a single, unified task that represents the shared meaning and conclusions of the group as a unit. It is a "coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" (Rochelle & Teasley,1995, p.70). Although partners may vary in ability level, neither child takes the role of expert or novice, tutor or tutee.

Collaborative work between students is perceived, by educators, as a valuable educational activity that enhances learning through active participation, teaches children to work together cooperatively in preparation for their transition into the wider community, and maximises the use of limited technological resources (De Lisi & Golbeck, 1999). Such a perspective emphasises the social creation of knowledge and this idea has both empirical and theoretical support.

Research examining the relationship between peer interaction and cognitive development is often based on the theories of either Piaget or Vygotsky (Tudge, 1992). Studies grounded in a Piagetian constructivist framework (Dimant & Bearison, 1991; Druyan, 2001; Golbeck & Sinagra, 2000; Kruger, 1992; Light & Littleton, 1994; Slavin, 1992) largely support the view that it is the cognitive conflict arising from peer interaction that leads to cognitive change. However, researchers in the Vygotskian tradition (Garton, 1992; Garton & Pratt, 2001; Johnson & Johnson, 1994; Samaha & De Lisi, 2000; Tudge, Winterhoff & Hogan, 1996) argue that cognitive development is most likely to occur when a child collaborates with a more competent partner.

Research shows that children working collaboratively together obtain a total higher performance output than children working individually (Moshman & Geil, 1998; Samaha & De Lisi, 2000; Underwood, Underwood, & Wood, 2000). However, peer collaboration is not always associated with individual cognitive change (Doise & Mugny, 1984; Levin & Druyan, 1993; Tudge & Winterhoff, 1993). It is suggested that the cognitive benefits of peer collaboration may depend on a complex set of factors such as age (Hogan & Tudge, 1999), comparative ability level of partners (Garton & Pratt, 2001), motivation (Gabriele & Montecinos, 2001), confidence (Tudge, Winterhoff, & Hogan, 1996), gender (Strough, Berg, & Meegan, 2001) and the task (Phelps & Damon, 1989). Some researchers (e.g., King, 1999; Kruger, 1992; Light & Littleton, 1994; Rogoff, 1990; Samaha & De Lisi, 2000; Teasley, 1995; Webb & Favier, 1999) argue that a key element of effective collaboration is the active exchange of ideas through verbal interactions.

This paper considers elements of Piaget's and Vygotsky's cognitive development theories that may help explain some of the processes underlying peer collaboration, which lead to cognitive change. Within both theories, cognitive development is regarded as an active process, requiring social facilitation for optimum growth. It is argued that

verbal communication is an important component of any social interaction and thus fundamental to effective peer collaboration and hence cognitive change.

Piaget's Theoretical Perspective

Piaget (1959) held that children's cognitive development depended on manipulation of, and interaction with, the environment. Through their experiences and interactions, children actively built systems of meanings and understandings of reality. Central to this learning process was the dynamic and self-regulatory mechanism of equilibration which co-ordinated the processes of accommodation and assimilation. Assimilation involved incorporating and understanding new information within existing schematic structures, whereas accommodation referred to schematic changes that occurred after contact with novel information. A state of disequilibration arose when there was an imbalance between what was encountered and what was understood. The process of restoring balance, and hence equilibration, through the development of new schemes or adaptation of existing ones, resulted in the construction of new knowledge, and therefore cognitive change. Piaget further argued that cognitive development was constrained by children's current stage of development and their state of intellectual readiness.

Piaget's (1959) model of equilibration assumed that cognitive conflict was the mechanism that engendered cognitive growth. Dimant and Bearison (1991) distinguished between cognitive conflict occurring in the intraindividual plane and sociocognitive conflict occurring in the interindividual plane. They argued that, according to Piaget, the operational regulations, by which conflict moderated reasoning, were the same whether the conflict arose intraindividually in the course of solitary reflection, or whether they arose interindividually in the course of social interaction. Thus both intraindividual and interindividual conflicts were believed to bring about cognitive growth.

The concept that cognitive conflict is the underlying mechanism of cognitive change is supported by a number of earlier Piagetian studies. The three mountains task (see Garton, 1992) is a spatial perspective task that involves conflict between the visual perspectives of different participants. It requires the active manipulation of task material, allowing for the expression of verbal as well as enactive disagreements between participants. Piagetians argue that this conflict forces participants to reconsider their own perspective before adopting or rejecting it in favour of another. Generally, the final position is more advanced cognitively than that held previously.

The impact of cognitive conflict on cognitive change has also been investigated using conservation tasks (see De Lisi & Golbeck, 1999). Children are pre-tested individually to determine their status as conservers or non-conservers in some domain. A conserver is then paired with a non-conserver and the children are asked to reach consensus on conservation type problems. It is argued that the conservers' different perspectives induce cognitive conflict in the non-conservers requiring non-conservers to reflect on, and ultimately restructure, their understanding of the problem. Individual post-testing usually indicates attainment of conservation for the non-conservers.

Cognitive conflict can also be operationalised as the verbal expression of different perspectives. Light and Glachan's (1985) study found that pairs who engaged in more frequent disagreements were subsequently more effective at solving detour problem-solving tasks than those where disagreement was infrequent. More recently, Johnson and Johnson (1994) found that controversy produced higher achievement than concurrence seeking. They concluded that controversy tends to result in greater mastery and retention of the subject matter being studied as well as greater ability to generalise the principles learned to a wider variety of situations.

From a Piagetian perspective, peer collaboration provides an ideal setting to promote cognitive conflict by exposing children to differences in skills or view-points,

resulting in disequilibration (Golbeck & Sinagra, 2000). Through dialogue and discussion with their peers, children re-examine, reconcile or restructure their understanding in light of others' conflicting input until equilibration is restored. As each child constructs a more coordinated, objective understanding of the task, cognitive change occurs.

Research by Dimant and Bearison (1991) indicated that children working in dyads do generate sociocognitive conflict that enables them to solve problems at a more advanced level than children working individually on the same problem. They found that dyadic interactions in which disagreements, contradictions and contrary solutions were expressed in a balanced fashion between partners were more effective in promoting cognitive gain than were dyadic interactions that lacked these kinds of cognitive disconfirmations. In other words, the interchange of thought with peers in interactive contexts followed the same principles of equilibration, as does intraindividual thought. However, although social interaction may stimulate and facilitate cognitive activity, the cognitive restructuring must take place on an individual level and cannot occur unless the child is cognitively ready and can capitalise on the conflict (Garton, 1992).

Piaget (1959) believed that, to counter children's tendency toward overly subjective assimilation and overly docile imitative accommodation, co-operative rather than unilateral social exchanges were needed. It is argued that such cooperative relations are more likely to occur when children interact with other children, rather than with adults. Underpinning this hypothesis is the suggestion that children intrinsically perceive that, in a symmetrical power and knowledge relationship, other legitimate perspectives exist (Garton, Harvey & Pratt, 2002).

The role of peers in cognitive development (in contrast to adult interaction), from a Piagetian perspective, has mostly been studied in the context of moral development (Kruger, 1992; Kruger & Tomasello, 1986). These researchers found that children

paired with a peer showed greater changes in moral reasoning than those paired with an adult. In addition, children's moral discussions with peers were qualitatively different from moral discussions with adults. Kruger analysed these discussion according to the participants' "spontaneously produced critiques, refinements, extensions or significant paraphrasing of ideas" (p.169), referred to as transactive statements. Peer dyads were characterised by their mutual use of other-oriented (response to partner's ideas) transactive statements. In contrast, adult-child dyads were characterised by a pattern of adult questions and child responses, and self-oriented (response to own ideas) transactions.

However, Tudge (2000) contends that the effectiveness of child-child interactions is not simply the result of equality of status. Rather a willingness to discuss actively how to solve problems and resolve those different perspectives to arrive at a shared understanding may be the underlying factor. This level of discussion and cognitive restructuring may arguably not occur in adult-child discussions on moral reasoning.

Thus from a Piagetian perspective, the cognitive benefits of peer collaboration result from the process of cognitive reorganisation induced by cognitive conflict. Such socially induced cognitive conflict is believed to most likely occur in cooperative peer dyads where children are actively engaged (rather than unilateral adult-child dyads) and in situations where children are at an appropriate stage of readiness.

Vygotsky's Theoretical Perspective

Researchers in the Vygotskian tradition argue that cognitive development is most likely to occur when two participants, who differ in terms of their initial level of competence, work collaboratively on a task to arrive at a joint understanding. Vygotsky (1978) viewed cognitive development as a sociogenetic process by which children gain mastery over cultural tools and signs in the course of interacting with others in the environment. Social contexts provide the learning arena in which the exchange of ideas

and the modelling of skills and strategies allow participants to internalise new knowledge and construct new meanings.

Like Piaget, Vygostky (1978) stressed the individual's active role in cognitive change: listening passively to an explanation or conflicting view, by itself, was not sufficient. Children also needed to determine inconsistencies between the expressed view and their own and then actively restructure their own view accordingly. In contrast to Piaget, Vygotsky saw development, not as a slow accumulation of unitary changes, but rather a "complex dialectical process, characterised by periodicity, unevenness in the development of different functions, metamorphosis or qualitative transformation of one form into another, intertwining of external and internal factors and adaptive processes" (p. 73).

A key element of Vygotsky's (1978) theory is the zone of proximal development, which he deemed more significant for the dynamics of intellectual development than the actual level of development. The zone of proximal development is the difference between what a child can accomplish independently (actual developmental level) and what can be achieved in conjunction with a more competent partner. It is a dynamic process that is continually changing in response to a child's increasing level of competence and understanding. It is not some clear-cut space, but rather indicates an individual's immediate potential for development created in the course of social interaction. Therefore, the zone may be different for children who are nominally at the same level of independent performance. Furthermore, although children can benefit from imitating that which is beyond the limits of their own independent capabilities, and they may be able to do more collaboratively than independently, children's performance is still restricted to limits determined by their developmental level as defined by their zone of proximal development.

Research (Forman, 1989; Moshman & Geil, 1998; Underwood, Underwood, & Wood, 2000) supports Vygotsky's (1978) hypothesis that children are able to solve more problems in collaboration than alone. However, Piaget took a somewhat negative view of such successes, claiming that they involve the teaching and learning of procedures and not the development of understanding (Wood, 1990). Yet, if children can subsequently complete similar activities independently, arguably collaboration does foster cognitive development. In addition, Garton, Harvey and Pratt (2002) suggest that the zone of proximal development implies a contribution towards the task goal by each participant as part of the collaborative process.

In Vygotsky's (1978) theory, the expert is viewed as having responsibility for adjusting the level of support or guidance required to fit the child's zone of proximal development. Wood (1990) referred to this as scaffolding. To scaffold effectively, the more capable children must plan, monitor and adapt their level of interaction according to their partner's needs. But are child peers capable of doing this and if so, how successful are they? Webb (1991) believes that peers are well equipped to satisfy some of the conditions for scaffolding. In particular, they have the potential for giving understandable, timely explanations and may understand better than teachers the specific aspects other students do not understand. In addition, peers are able to translate difficult vocabulary and explain concepts in more familiar terms.

Azmitia (1988) found that in preschool peer dyads, "expert" lego builders gave slightly more explanations and demonstrations to "novices" than to "experts". Although "experts" seldom monitored "novices'" performance, their observations usually led them to correct novices' building and to justify the correction. More recently, Yarrow and Topping (2001) sought to evaluate the relative contribution of metacognitive prompting and scaffolding to student gain in writing. Ten and 11-year-olds, trained in paired writing and metacognitive prompting and assigned to the interactive condition, showed

significantly greater gains on a post-test than those of the lone writers. King, Staffieri and Adelgais (1998) also demonstrated that peer interaction can be structured so that children can scaffold each other's higher order thinking and learning. Seventh graders, trained to use sequenced inquiry and explanations, outperformed explanation only, and explanation plus inquiry students, on their ability to construct knowledge.

According to Vygotsky (1978), the specific mechanisms that allow children to construct higher psychological structures, are internalisation and externalisation. Children internalise the processes occurring in the course of the interaction with more competent partners. It is not merely copying, but requires children to transform the internalised interaction on the basis of their own characteristics, experience and existing knowledge. Thus the development of cognitive skills appears twice; firstly on the social plane, between people as an interpsychological process; and then within the child as an intrapsychological process. Social and cognitive processes are therefore seen as interdependent and equally integral to learning (Hogan & Tudge, 1999). So, although Vygotsky emphasises social processes, like Piaget, he viewed cognitive development as a process of reorganising mental structures.

Intersubjectivity is another of Vygotsky's (1978) key concepts. It arises when two individuals, who begin a task with a different understanding, arrive at a shared understanding in the course of communicating their viewpoints. Thus arguably, if partners already have the same subjective understanding of the task, the situation is little different than exploring the task alone and consequently, development is less likely to occur than if they had different initial understandings (Tudge, 1992). However, initial differences in understanding will not lead to development if one partner simply agrees with the other's viewpoint – in which case intersubjectivity would not have been attained.

The lack of intersubjectivity could explain why children paired with adults in Kruger's (1992) moral reasoning research showed little cognitive change. The adult-child dyads were characterised by passive acceptance of the adult viewpoint, suggesting these dyads did not arrive at mutually agreed upon solutions. Arguably, these children did not internalise the process, which is a requisite for cognitive change. Forman's (1989) work also indicated that successful achievement of intersubjectivity required that children coordinate their interpersonal wishes to dominate or please their partner with the need of the dyad to work together to solve the problem. Therefore, taking responsibility for achievement is central to the learning mechanism (Garton, 1992).

From a Vygotskian perspective, it is peer cooperation, not conflict, that enhances cognitive development in peer collaboration. In this situation, children solve problems together by establishing a joint definition of the situation, one that reflects each other's understanding. They construct a mutually satisfying solution by coordinating and integrating their different viewpoints. But is this really so different from a Piagetian perspective? It would seem that in both instances, if partners commence with the same understanding, then neither is likely to benefit from the interaction.

Language

Several researchers have questioned the cognitive efficacy of peer collaboration for individuals (e.g., Dimant & Bearison, 1991; Hogan & Tudge, 1999; Kruger, 1992; Messer & Joiner, 1993; Phelps & Damon, 1989; Teasely, 1995; Tudge & Winterhoff, 1993; Webb, 1991). These researchers seem to agree that merely working together is not sufficient to improve the performance of the individuals involved. But rather, the quality of the interaction and the active exchange of ideas appear to be integral, underlying factors.

Studies by Teasley (1995) and Garton, Harvey and Pratt (2002) found that the total number of utterances used between peer collaborators was significantly associated

with improvement in reasoning strategies or problem solving ability. Kruger's (1992) and Mackie's (1983) studies showed that children who engaged in active debate were more likely to benefit cognitively, than those who were described as passive listeners. Similarly, Tolmie, Howe, Mackenzie and Greer (1993) found that the most important element of on-task activity was dialogue between group members.

Even when children are working alone, the production of self-talk that consists of articulating reasons or motives is positively related to performance (Teasley, 1995). Thinking aloud can alter the individual's knowledge structure and affect subsequent performance by clarifying and/or elaborating ideas, evaluating existing knowledge for accuracy and gaps, integrating and reorganising information or in some other way reconceptualizing the material (King, 1999). This type of verbalisation is believed to improve performance because it requires interpretative processing to link information in the individual's short-term memory to thoughts or information attended to previously (Ericsson & Simon, 1984).

Yet, more frequent talk does not always lead to improved cognitive skills. Chi, de Leeuw, Chiu and La Vancher (1994) found that the content, rather than the actual amount of speech (as measured by protocol lines), differentiated between good and poor problem solvers. Good problem solvers stated rules, generated more explanations, and monitored and evaluated their actions. Chi et al. argue that such verbalisation is beneficial because it provokes internal, interpretive processing. In Dimant and Bearison's (1991) study, only participants who demonstrate a greater than average number of theoretically relevant types of interaction (statement indicating agreement or disagreement, explanations and questions) evidenced significant gains in formal reasoning skills. Similarly, in Barbieri and Light's (1992) study, pairs who negotiated most explicitly and made most extensive use of verbal preplanning while working collaboratively on a detour task tended to be the most successful at individual post tests.

Wegerif, Mercer and Dawes (1999) differentiate between three types of talk: disputational talk characterised by disagreement and individualised decision making; cumulative talk characterised by repetition, confirmation and elaboration; and exploratory talk in which partners engage critically but constructively with each other's ideas leading to eventual joint agreement. Researchers who have analysed the different types of talk occurring in dyads have found that successful dyads, compared to unsuccessful ones, engaged in more exploratory talk, provided more explanations (see Teasley, 1995), and engaged in more sophisticated arguments, clarification and negotiations (Perlmutter, Behrend, Kuo, & Muller, 1989). When Wegerif et al. taught 8- and 9- year-old children to use exploratory talk, both group reasoning and individual performance on the Raven's Standard Progressive Matrices improved. Exploratory talk is considered more valuable for learning because there is no automatic consensus (as with cumulative talk) or unproductive dispute (as with disputational talk) but rather productive argument, questioning and exploration (Mercer, 1996).

Webb (1991) examined children's interactions and found that giving content related explanations was positively and significantly related to achievement. Similarly, Foreman and McPhail (1993) found that partners were more likely to show cognitive growth when they listened to each other's explanations, and reflected on their logical consistency and precision. Webb suggests that providing explanations requires the reorganisation, clarification and evaluation of knowledge. This may help the explainer develop new perspectives, recognise and reconcile inconsistencies, construct more elaborative understandings and consequently learn the material better. However, the benefits of receiving explanations are not so clear cut and seem to depend on whether the student needed help, the relevance of the explanation, timeliness, extent the explanation is understood, the ability to internalise the information and the opportunity to correctly use the information to solve a similar problem (Webb, 1989). Thus students receiving

explanations need to process them and adequately relate the new information to existing knowledge structures for learning to occur.

It has been contended that active communication is an important mediator for cognitive change in collaborative settings. But how can this perspective be reconciled with the theories of Vygotsky and Piaget?

Wood (1990) suggested that the most widely reported difference of opinion between Vygotsky and Piaget concerned the nature of language and its effect on intellectual development. Language for Piaget (1959) was described as a system of symbols for representing the world, as distinct from actions and operations that form the processes of reasoning. Although Piaget argued that language did not create the structure of thinking, he conceded that language facilitates its emergence. In addition, he accepted that social interaction was an important component of intellectual development. Talking to others (particularly peers) often provokes some form of cognitive disconfirmation, triggering a search for logical coherence and deliberate attempts to improve understanding following the cognitive perturbation.

Piaget (1932) also saw social experience as an important factor in overcoming the barrier of egocentrism, which limited children's moral thinking, communication and cognitive development. In a symmetrical relationship between children and their peers, differences of viewpoint could provide both a divergence of views and the social pressure to reach a resolution. Differing perspectives, arising from different levels of understanding, generate a need to convince both oneself and other group members of the correctness of a given position. The resulting reflection, questioning and explanations give rise to cognitive restructuring and consequently cognitive growth. Without communication, there could be no conflict, disagreement, agreement, negotiation nor resolution.

Doise and Mugny (1984) and Perret-Clermont (1980) found that interactions characterised by conflict and negotiation resulted in larger cognitive gains, lending support to the idea that it is socio-cognitive conflict (the holding of different viewpoints by different partners in a social interchange) that holds the key to cognitive change. These researchers argued that non-conserving children who showed cognitive gain after social interaction were not simply imitating their more advanced peer. Rather, the conflict created by interacting with conserving children prompted and stimulated cognitive activity, leading to the restructuring of the non-conserving children's cognitive representations.

In particular, Piaget (1932) postulated that social interaction had a facilitatory effect on children's developing understanding of morality. He demonstrated that groups of children were able to solve moral problems collectively in advance of their individual ability. Cognitive changes (particularly in less advanced children) were attributed to the integration of different perspectives into a common resolution, through interpersonal discussion and debate.

Working in a Piagetian framework, Kruger and Tomasello (1986) and Kruger (1992) examined moral discussions of 7- to 10- year-old girls paired with a peer or an adult. These studies found an important difference in the quality of the discussion between peer and adult dyads. The use of active reasoning (across both peer and adult-child dyads) to discuss moral dilemmas was predictive of change in moral reasoning. However, active reasoning occurred more frequently in peer transactions where children were actively involved, compared to adult-child transactions where children assumed more passive roles.

From a Piagetian perspective, Kruger's (1992) findings suggest that symmetrical peer relationships facilitate the use of language that leads to cognitive change. However, it could equally be argued that active and mutual verbal engagement, as opposed to the

equality of the relationship, was the more critical factor in cognitive change. Forman (1989) proposed that in situations where power and knowledge are unequal, the relationship tends to be defined by complementarity of interaction (one teaches, while one learns). In contrast, equal relationships tend to be defined by reciprocity of interaction, and thus a shared communicative situation is more likely to be negotiated and established. Yet, if children have the opportunity to reflect on their own understanding and actively explore the views of others, then arguably it is the active interaction with different perspectives that is the critical factor. This could occur in equal and unequal relationships providing that one person does not dominate the interaction. In fact Piaget (as described by Tudge & Winterhoff, 1993) does suggest that adults can serve as effective partners to children when they are able to "efface" themselves during their interactions and not simply act as a dominant authority figure. Therefore, it is suggested that to understand how collaboration impacts on cognitive change, it is necessary to evaluate the dynamics of interpersonal interaction as well as the communication process.

An alternative explanation is that the experience of working with peers on a task changes the way children understand the question. The work of Donaldson (1978) suggests that children often fail Piagetian tests because they misunderstand the questions. A break down in communication at any level may account for children's apparent illogicality. Young children may appear to understand and use particular words and expressions in familiar situations, but are the same meanings applicable in contrived experimental tasks? Van Lehn, Jones and Chi (1992) proposed that verbalisation helps problem solving by identifying the missing components of a solution and formalising the required steps. Thus peer interaction may allow children to better understand the underlying expectations, leading to improved performance.

To Vygotsky (1978), language was a powerful mediating mechanism in cognitive development, critical in the development from "natural" to "higher" mental processes. Vygotsky was concerned with how speech was interrelated with other aspects of social and individual activity, and how it informed analyses of reasoning and other forms of goal directed action (Wertsch, 1993). He argued that language preceded rational thought and influenced the nature of thinking. Thus language in a Vygotskian framework was fundamental to all knowledge, both as an interpersonal, communicative system and as a cognitive, representational system permitting development (Garton, 1992).

For Vygotsky (1978) language provided the very means by which reflection and elaboration of experience takes place. Thus knowledge was perceived to be created in the course of interacting with others: first it is social and then later, individual. Interactions considered effective are ones that support students' engagement in higher order cognitive processes (King, Staffieri, & Adelgais, 1998). Such interactions include providing elaborate explanations, asking appropriate questions, providing sufficient time for the partner to think, and using supportive communication skills such as listening, giving feedback and encouragement. Shachar and Sharan (1994) found that when students were involved in cooperative activities that encouraged them to use language as a medium with which to represent their ideas, relate to others, discuss how to proceed and to restructure their ideas in light of the different perspectives of others, they used a more diverse and sophisticated range of thinking strategies.

Scholars in the Vygotskian tradition have stressed the need for children to achieve joint understanding of a problem, on the basis of taking another's perspective into account, for thinking to advance (van Boxtel, van der Linden, & Kanselaar, 2000; Tudge, 1992; Rogoff, 1991). King (1999) contended that when individuals interact in cooperative discussions they are able to discover conceptual discrepancies in their own perceptions and general understanding of the topic. This leads them to negotiate

meaning and co-construct knowledge through explaining, questioning, evaluating, defending, speculating and revising to reconcile the discrepancies. According to Vygotsky's theory, learning occurs during such high level discourse because the interactive process results in the reorganising and restructuring of the individual's own knowledge and thinking which would not occur to the same extent if working alone.

The importance of active, reasoned dialogue in the above studies points to a common ground for both Piaget's and Vygotsky's theoretical orientations (Webb & Favier, 1999). In the Vygotskian approach receiving explanations from a more capable peer enables the less capable child to correct misconceptions, fill in gaps in understanding, strengthen connections between new information and previous learning and develop new problem solving skills and knowledge. In the Piagetian perspective, the process of resolving cognitive conflict through explanation and justification enables children to clarify or reorganise material in new ways, recognise and fill gaps in understanding, recognise and resolve inconsistencies, develop new perspectives and construct more elaborate conceptualisations.

By combining these two theories, it is suggested that the benefits of peer collaboration arise from giving and receiving explanations from a partner who has a different perspective, due either to more or different knowledge, or a different viewpoint (Kruger, 1993). Socio-cognitive conflict is created when the child becomes aware of an opposing view point. Co-operative, co-construction occurs when two individuals explore each other's thoughts and together create a new, integrated perspective. For both theories, it is crucial that peer interaction focuses on the content and rationale of that which is different, in order for cognitive change to occur.

Active Participation

The literature suggests that cognitive change, in group settings, requires active participation in the learning process and engagement in constructive activity. Active

participation of the learner is a critical feature of both Piaget's (1959) and Vygotsky's (1978) perspectives on learning. In Piaget's theory the learner is actively involved in resolving cognitive conflict. In Vygotsky's theory the learner actively interprets functions occurring in social interaction with a more competent partner. In both theories, for cognitive change to occur, children must actively internalise the new information so it becomes a part of their individual repertoire and enables correct performance, without assistance.

Forman and Cazden (1985) discerned three types of peer interaction: a parallel form characterised by no verbal exchange; an associative form in which children tried to exchange information but did not coordinate their roles; and a cooperative form in which both children constantly monitored each other's work and coordinated roles to carry out tasks. Cooperative interaction was positively associated with more advanced cognitive operations in reaching solutions to the task and learning.

Webb and Favier (1999) suggest that carrying out further activity after receiving explanations from a partner may benefit children in several ways. Firstly, during the process of using the explanation to solve a problem, children may generate self-explanations that help them internalise principles and construct specific, applicable inference rules. Secondly, attempts to solve problems may help children more accurately monitor their understanding of the task, avoiding a false sense of competence.

The extent to which children can engage in active collaboration and verbalisation is in part a reflection of the type of task and relative task difficulty. Willems (1981) suggested that problems can be conceptualised along a continuum, ranging from those for which the data are clearly specified and the solution is obvious, to those for which the learner must select the relevant information and for which there are several solutions. Phelps and Damon (1989) found that peer collaboration promoted basic conceptual development using discovery learning tasks, but did not foster rote learning, that relied

on formulas and procedures. In addition, Perlmutter, Behrend, Kuo and Muller (1989) found that tasks of moderate difficulty were more likely than easy or difficult tasks to produce effective verbalisation and hence, active collaboration. This research suggests that, although closed-ended, result focused tasks may reinforce earlier learning, they do little to encourage new understanding. In contrast, open-ended, problem solving type tasks are likely to encourage greater opportunities for collaboration and cognitive change.

Conclusion

Research does indicate a performance benefit for children working collaboratively, compared to children working individually. However, the longer term cognitive benefits of collaboration for individual children appear to be limited by a number of factors, including type of task, level of participation, nature of language exchanges and relative abilities of group members. More specifically, it is suggested that cognitive change following peer collaboration is limited to children working with a more cognitively competent peer, or one with a different perspective. In addition, active participation and reasoned communication seem to be critical underlying factors.

The benefits of peer collaboration are historically explained with reference to the cognitive development theories of Piaget or Vygotsky. However, it is suggested that these two theories are not as mutually exclusive as they are often portrayed. Both theories suggest that learning is a result of active interaction. In Vygotsky's theory the focus is on social interaction with more "expert" others. While Piaget focuses on the cognitive conflict produced through exposure to different perspectives. Yet arguably the important component in both theories is that cognitive change results when the interaction exposes a participant to a different knowledge source, whether it be due to a conflicting perspective (as argued by Piagetians) or a higher level of expertise (as argued by Vygotskians).

In both Piaget's and Vygotsky's theory, the resolution of the resulting mismatch between a child's current cognitive understanding and information provided in the interaction appears to be the underlying key to cognitive change. This process requires children to re-examine, reconcile or restructure their understanding, leading to internal reorganisation and a more coordinated, objective understanding.

Arguably, this reflective process occurs most successfully through dialogue and discussion. Traditionally Piagetians have argued that children are more likely to engage in this process when interacting with other children. In contrast, Vygotskians have focused on adult-child interactions. Yet, social interaction implies a degree of reciprocity and bidirectionality between participants and thus active involvement of all parties. Consequently, it is suggested that it is the relative contribution (both quality and quantity) of each participant in the interaction that affects the nature and outcome of cognitive change. Thus, the important criteria are not the relative equality of the participants but rather the level of opportunity, and the complexity of the discussion and reasoning, necessary for internal reorganisation to occur.

Theoretically then, the cognitive value in peer collaboration appears to be linked to two main factors. Firstly, the interaction needs to be with a more competent partner, or one with a different knowledge base, to ensure there is the necessary mismatch required to promote the re-examination of the child's own understanding which leads to internal reorganisation and cognitive change. Secondly, the child must be an active participant. Active involvement in the task and participation in elaborate communication appear to be the facilitatory mechanisms through which cognitive restructuring and hence cognitive change occurs.

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Running head: Peer Collaboration and Problem Solving

The Effect of Peer Collaboration on Children's Problem Solving

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Abstract

The current study aimed to investigate the effect of collaborative learning on children's problem solving ability and whether differences in knowledge status or the use of explanatory language were contributing factors. One hundred Year 2 children (aged 6 to 7 years), from schools in high socio-economic areas, individually completed a pre-test and post-test comprising a block sorting task. During the experimental phase children completed a card sorting activity, either individually or in same-gender dyads. The dyads consisted of same or different ability children who operated under either a talk or no-talk condition. It was found that children who collaborated collectively obtained a significantly higher number of sorts than children who worked individually. However, post-testing indicated that only those children of lower sorting ability who collaborated with higher sorting ability peers showed a significant improvement in sorting ability from pre-test scores. In addition, it was found that when analysis was limited to this particular group, only those children, who were required to explain the sort for their partner to carry out, improved significantly from pre-to post-test. The study was grounded in a Vygotskian framework, which links cognitive change to collaboration with a more competent partner. However, it is contended that the results could also be interpreted from Piagetian perspective, which supports the view that cognitive conflict arising from peer interaction leads to cognitive change. It is suggested that perhaps the two theories are not as mutually exclusive as they are often portrayed. Implications of these findings for teachers are also discussed.

The Effect of Peer Collaboration on Children's Problem Solving Ability

Collaborative learning, along with other types of peer-based, small group instruction, is a commonly used teaching strategy in many Western Australian classrooms. Collaborative work is perceived by educators as a valuable educational activity that enhances learning through active participation, teaches children to work together cooperatively in preparation for their transition into the wider community, and maximises the use of limited technological resources (De Lisi & Golbeck, 1999). But how effective is peer collaboration as a learning strategy? How should children be grouped? What factors are integral to the collaborative learning process? And, in what theoretical framework can the underlying cognitive processes of peer collaboration be best understood?

Peer collaboration (as distinct from peer tutoring or co-operative learning) involves children working together to complete a single, unified task that represents the shared meaning and conclusions of the group as a unit. It is a "co-ordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" (Rochelle & Teasley, 1995, p.70). Although partners may vary in ability level, neither child takes the role of expert or novice, tutor or tutee.

Research examining the relation between peer social interaction and cognitive development has usually been based on the theories of either Piaget or Vygotsky (Tudge, 1992). Piaget (1959) held that a child's cognitive development depended on manipulation of, and active interaction with, the environment. Central to this learning process were states of disequilibrium, due to an imbalance between what was understood and what was encountered. Piaget suggested that peer interaction promoted cognitive conflict by exposing discrepancies between their own and others' knowledge, resulting in disequilibration. As a higher level of understanding emerged, through dialogue and

discussion among individuals of equal status, equilibration was restored and, simultaneously, cognitive change occurred. Studies grounded in a Piagetian constructivist framework have largely supported this view that working with a peer leads to greater cognitive benefit than working alone (Dimant & Bearison, 1991; Druyan, 2001; Goldbeck & Sinagra, 2000; Kruger, 1992; Light & Littleton, 1994; Slavin, 1992).

However, researchers in the Vygotskian tradition argue that cognitive development is most likely to occur when two participants, who differ in terms of their initial level of competence, work collaboratively on a task to arrive at a shared understanding (Garton, 1992; Johnson & Johnson, 1994). Within this perspective there are two key concepts: zone of proximal development and intersubjectivity (Vygotsky, 1978). The zone of proximal development is the difference between what a child can accomplish independently and what can be achieved in conjunction with a more "expert" partner. Intersubjectivity is the shared understanding that results from individuals discussing their differing viewpoints. The "expert" is viewed as having responsibility for adjusting the level of support or guidance required (scaffolding) to fit the "novice's" zone of proximal development. Studies grounded in a Vygotskian framework have supported the view that cognitive development depends on active, social interaction with a more competent partner who has a different subjective understanding of the task (Garton, 1992; Garton & Pratt, 2001; Samaha & De Lisi, 2000; Tudge, Winterhoff, & Hogan, 1996).

Research shows that children working collaboratively obtain a combined higher performance output than children working individually (Moshman & Geil, 1998; Samaha & De Lisi, 2000; Underwood, Underwood, & Wood, 2000). However, peer collaboration is not always associated with individual cognitive change (Doise & Mugny, 1984; Levin & Druyan, 1993; Tudge & Winterhoff, 1993). It is suggested that the cognitive benefits of peer collaboration may depend on a complex set of factors such

as age (Hogan & Tudge, 1999), comparative ability level of partners (Garton & Pratt, 2001), motivation (Gabriele & Montecinos, 2001), confidence (Tudge, Winterhoff, & Hogan, 1996), gender (Strough, Berg, & Meegan, 2001) and the task (Phelps & Damon, 1989). Some researchers (e.g., King, 1999; Kruger, 1992; Light & Littleton, 1994; Rogoff, 1990; Samaha & De Lisi, 2000; Teasley, 1995; Webb & Favier, 1999) argue that a key element of effective peer collaboration is the active exchange of ideas through verbal communication.

Studies by Teasley (1995) and Garton, Harvey and Pratt (2002) found that the total number of utterances used between peer collaborators was significantly associated with improvement in reasoning strategies or problem solving ability. Kruger's (1992) study showed that children who engaged in active debate were more likely to benefit cognitively than those who were described as passive listeners. In Barbieri and Light's (1992) study, pairs who negotiated most explicitly and made most extensive use of verbal preplanning while working collaboratively on a detour task tended to be the most successful at individual post tests. Similarly, Foreman and McPhail (1993) found that partners were more likely to show cognitive growth when they listened to each other's explanations, and reflected on their logical consistency and precision. Verbalisation is believed to improve performance because it requires interpretative processing to link information in the individual's short-term memory to thoughts or information attended to previously (Ericsson & Simon, 1984).

Although Piaget (1932) argued that language did not create the structure of thinking, he conceded that language facilitated its emergence. In addition, he accepted that social interaction was an important component of intellectual development. Talking to others (particularly peers) often provokes some form of cognitive disconfirmation, triggering a search for logical coherence and deliberate attempts to improve understanding following the cognitive perturbation. Findings from Kruger's (1992)

study on moral reasoning supported the Piagetian perspective that symmetrical, peer interactions (compared to adult-child dyads) facilitated the use of language and hence cognitive change. However, if children have the opportunity to reflect on their own understanding and actively explore the view of others, then arguably it is the active interaction with a different perspective that is the critical factor. This could occur in equal and unequal relationships providing that one person does not dominate the interaction (i.e., adults or "experts" are prepared to efface themselves).

To Vygotsky (1978), language was a powerful mediating mechanism in cognitive change, critical in the development from "natural" to "higher" mental processes. Language, through the course of interacting with others, provided the tools for reflection and elaboration of experience. Verbal interactions considered effective are ones that support students' engagement in higher order cognitive processes (King, Staffieri, & Adelgais, 1998). Such interactions include providing elaborate explanations, asking appropriate questions, providing sufficient time for the partner to think, and using supportive communication skills such as listening, giving feedback and encouragement (Webb & Favier, 1999). According to Vygotsky's theory, learning occurs during such high level discourse because the interactive process results in the reorganising and restructuring of the individual's own knowledge and thinking which would not occur to the same extent if working alone.

The importance of active, reasoned dialogue in the process of cognitive change points to a common ground for both Piaget's and Vygotsky's theoretical orientations (Webb & Favier, 1999). From the Vygotskian perspective, receiving explanations from a more capable peer enables the less capable child to correct misconceptions, fill in gaps in understanding, strengthen connections between new information and previous learning and develop new problem solving skills and knowledge. From the Piagetian perspective, the process of resolving cognitive conflict through explanation and justification enables

children to clarify or reorganise material in new ways, recognise and fill gaps in understanding, recognise and resolve inconsistencies, develop new perspectives and construct more elaborate conceptualisations.

By combining Piaget's and Vygotsky's theories, it is suggested that the benefits of peer collaboration arise from active participation and verbal communication with a partner who has a different perspective, due either to more or different knowledge, or a different viewpoint (Kruger, 1993). Socio-cognitive conflict is created when the child becomes aware of an opposing viewpoint. Co-operative, co-construction occurs when two individuals explore each other's thoughts and together create a new, integrated perspective. For both theories, it is crucial that peer interaction focuses on the content and rationale of that which is different, in order for cognitive change to occur.

Theoretically then, the cognitive value of peer collaboration appears to be linked to two main factors. Firstly, the interaction needs to be with a more competent partner, or one with a different knowledge base, to ensure there is the necessary mismatch required to promote the re-examination of the child's own understanding which leads to internal reorganisation and cognitive change. Secondly, the child must be an active participant. Active involvement in the task and participation in elaborate communication appear to be the facilitatory mechanisms through which cognitive restructuring and hence cognitive change occurs.

This current study aimed to extend work conducted by Garton and Pratt (2001), to investigate the effect of peer based collaborative learning on 7-year-old children's problem solving ability, and whether differences in knowledge status or the use of explanatory language were contributing factors. The research used an interactive problem-solving paradigm, conducted under the rubric of Vygotsky's theory of cognitive development. Children were paired with peers of similar or different problem-solving ability on the basis of pre-testing, or alternatively were allocated to the control condition

where they worked independently. To explore the effect of language, a comparison was made between dyads where active communication was a requirement of the task and dyads where verbal interaction was discouraged.

It was hypothesised that children with lower cognitive ability working collaboratively with a peer of higher cognitive ability would show greater cognitive gain from pre- to post-test compared to children working with peers of similar or lower cognitive ability or children working on the same task alone. Secondly, it was hypothesised that lower ability children working collaborative with a higher ability peer would show greater cognitive change from pre- to post-test when they were instructed to provide elaborate explanations, compared to those pairs in which verbal interaction was minimised.

Method

Participants

One hundred and twenty-five Year 2 children, from five state primary schools in the suburbs of Perth, Western Australia, participated in this study. The schools each had an 8 rating on the H-Index[1] (based on socio-economic status) and consisted predominantly of Caucasian students. Permission from the school principal and Year 2 teachers, written parental consent and child agreement were pre-requisites to participation. On average there was an 80% participation rate per school.

Children were allocated to either a high or low differential cognitive status (representing high and low sorting ability) defined on the basis of a pre-test sorting task. This resulted in 50 children being defined as "high sorting ability" and 75 children defined as "low sorting ability". Twenty-five children from the "low sorting ability" group were then randomly excluded from the study to ensure equal numbers in each

[1] The H-Index used in Western Australian government school is based on an analysis of census data and is based on the dimensions of occupation, income, family structure, accommodation, tenancy, English language competence and Aboriginality. Band 8 schools are located in districts with the highest ratings on each of these dimensions, excluding Aboriginality (Louden & Wildy, 2001).

condition. The final sample consisted of 52 boys and 48 girls, with a mean age of 7 years, 0 months (SD= 4 months, range=6 years, 1 month to 7 years, 9 months).

Children were matched to a partner (or allocated to a control group) on the basis of their cognitive status resulting in 10 pairs of high/high scorers, 10 pairs of low/low scorers, and 20 pairs of high/low scorers. Twenty children (10 high scorers and 10 low scorers) did not engage in the collaborative activity, but worked independently in the experimental phase to control for any practice effects associated with completing this task and to provide a comparison of the effect of collaboration on performance for the experimental task.

Materials

The study utilised two sorting tasks. Attribute blocks comprising three colours, two shapes, two sizes and two widths were used for the pre- and post-test. Children were required to sort the blocks individually, yielding a maximum of 14 possible sorts – by colour (three piles), by shape (two piles), by size (two piles), by width (two piles), by colour and shape (six piles), by colour and size (six piles), by colour and width (six piles), by shape and size (four piles), by shape and width (four piles), by size and width (four piles), by colour, shape and size (12 piles), by colour, size and width (12 piles), by shape, size and width (eight piles), by colour, shape, and width (12 piles).

A set of cards depicting clothing (see Appendix A) comprising three articles of clothing (trousers, shirt, skirt), two letters (M, B), three designs (flowers, squares, stripes) and two trims (lace, no lace), were sorted in the experimental task. A maximum of 14 sorts were possible - clothing; letters; designs; trims; clothing and letters; clothing and designs; clothing and trims; letters and designs; letters and trims; designs and trims; clothing, letters and designs; clothing, letters and trims; clothing, designs and trims; letters, designs and trims; clothing, letters, designs and trims.

Procedure

Ethics approval for the study was obtained from Edith Cowan University Faculty Ethics Committee. Children completed all components of the study (either individually or in pairs) in an area, separate from their classroom, supervised by the same female experimenter. Children's initial sorting ability was assessed individually using the attribute blocks. On average, children indicated their inability to complete further sorts after 7 minutes, 29 seconds (SD=3 minutes, 2 seconds, range = 1 minute, 25 seconds to 16 minutes, 23 seconds).

Children obtained a pre-test score of between 0 and 9 different sorts (maximum of 14). In accordance with previous research by Garton and Pratt (2001), children scoring between 1 to 4 sorts were classified as "low sorting" ability and those scoring above 5 were classified as "high sorting" ability. Children, within a class, were then matched with a partner of the same gender[2] and according to one of three experimental conditions (high/high, low/low, or high/low sorting ability) or one of the two control groups (high or low sorting ability). Four children were allocated to the control groups for every eight children allocated to experimental conditions. Children allocated to the high/low condition differed by at least three sorts. Children allocated to the high/high or low/low conditions had identical pre-test scores.

Pairs in each of the experimental conditions were then randomly divided into two levels of interaction ("elaborate explanations" where children were required to explain the sort for their partner to carry out or "minimal verbal interaction" where talking was discouraged and children carried out their own sort) and given precise instructions (see Appendix B) according to the experimental condition to which they were assigned. The experimental task consisted of children working collaboratively in pairs (or individually in the control condition) to sort the clothing cards, in as many different ways as possible

[2] Research (Strough, Berg & Meegan, 2001; Strough & Cheng, 2000; Strough & Diriwachter, 2000) indicates that same gender dyads results in greater shared goals and consequently better performance.

(maximum of 14). On average, children indicated their inability to complete further sorts after 16 minutes, 24 seconds (SD= 6 minutes, 13 seconds, range = 3 minutes, 24 seconds to 30 minutes, 32 seconds).

Children's ability to sort attribute blocks was reassessed the week following the experimental session to evaluate whether collaboration facilitated improved performance. On average, children indicated their inability to complete further sorts after 7 minutes, 22 seconds (SD = 3 minutes, 5 seconds, range = 2 minutes, 32 seconds to 19 minutes, 32 seconds).

Results

Analysis of the data indicated no significance skewness or kurtosis and no outliers. Levene's test was significant ($p<.05$) indicating that the homogeneity of variance assumption had not been violated. A one way analysis of variance (ANOVA), comparing the difference between the number of sort obtained by those children who worked independently during the experimental phase and those who collaborated with a peer, showed a significant main effect, $F(1,100)=14.764$, $p<.01$. Children working together ($M=6.54$, $SD=1.70$) obtained, on average, 1.69 more sorts than those working independently ($M=4.85$, $SD=1.98$).

Table 1 shows the mean number of sorts (and the standard deviation) obtained for each condition in the pre-test and post-test attribute block sorting task and the mean difference between these two tests.

Table 1. Mean number of sorts (and standard deviations) by group and verbal interaction for pre-test and post-test and the mean difference between these two tests

Group	Explanations				No explanations			
(Ability Level)	N	Pre-test	Post-test	Diff	N	Pre-test	Post-test	Diff
Low/low	10	3.20 (0.79)	3.70 (0.82)	0.50 (0.71)	10	3.40 (0.52)	3.50 (0.97)	0.10 (0.88)
Low/high	10	2.90 (0.57)	5.00 (1.33)	2.10 (1.45)	10	3.10 (0.99)	3.80 (0.92)	0.70 (0.82)
High/low	10	6.80 (0.63)	6.90 (1.10)	0.10 (0.99)	10	6.70 (1.49)	6.10 (1.79)	-0.60 (1.14)
High/high	10	5.30 (0.48)	5.20 (0.63)	-0.10 (0.57)	10	5.00 (0.00)	4.80 (0.79)	-0.20 (0.82)

	N	Pre-test	Post-test	Difference
Control (low ability)	10	2.90 (1.20)	2.90 (1.20)	0.00 (0.82)
Control (high ability)	10	5.60 (0.70)	5.30 (0.82)	-0.30 (0.67)

Note. Standard deviation in parentheses.

Since hypothesis I concerned cognitive gain, and because children's initial sorting ability (as measured in the pre-test) varied significantly ($F(5,100)=65.178$, $p<.01$), the differences between children's pre- and post-test scores were used as the dependent variable[3] to compare relative improvement in sorting ability between the groups. A one way ANOVA showed a significant main effect of group ($F(4,100)=8.523, p<0.01$) and a main effect of explanations ($F(1,100)=5.929, p<0.05$), but no significant interaction. Tukey's HSD posthoc test showed that low ability children working with a high ability peer improved significantly ($p<.05$) from pre- to post-test compared to all other conditions. In contrast, children collaborating with a same or lesser ability peer, or working independently, showed no significant improvements in sorting ability from pre- to post-test, and there were no significant differences between these conditions. It is interesting to note that there was a tendency for high ability

[3] Garton and Pratt (2001) also used difference scores between pre- and post-test in their study.

children to regress from pre-test to post-test in all conditions except those working with a low achieving peer in the explanation condition.

Tukey's HSD posthoc test showed that the main effect of explanations was due to a significant pre- to post-test difference between the explanation and no explanation conditions ($p \leq .05$), and between the explanation and control group ($p < .01$). Children in the explanation condition ($M = .65$, $SD = 1.29$) improved more than those in the no explanation condition ($M = .15$, $SD = .95$) and those who worked independently ($M = -.15$, $SD = .75$). There was no significant difference between the no explanation and control groups.

Hypothesis 2 focused specifically on the effect of explanations when low sorting ability children collaborated with a higher sorting ability peer. A one way ANOVA, limited to this particular group of children, showed a significant main effect for explanations ($F(1,20) = 7.056, p < .05$). Those children who were required to explain the sort for their partner to carry out ($M = 2.1$, $SD = 1.45$) improved significantly from pre- to post-test, compared to those children where verbal interaction was minimal ($M = 0.7$, $SD = 0.82$).

Discussion

Most research on peer collaboration shows that children working collaboratively towards a common goal achieve a higher performance output compared to individual efforts (eg., Moshman & Geil, 1998; Samaha & De Lisis, 2000; Underwood, Underwood, & Wood, 2000). The current study provides support for this view in that during the collaborative phase 7-year-old children working in dyads on a problem-solving task obtained significantly more sorts compared to those children working individually. However, the greater productivity and achievement obtained during collaboration did not result in universal cognitive benefit for individual children outside the collaborative situation.

In the context of the sorting tasks used in this research, only those children, who were paired with a child of relatively higher ability during the collaborative phase, demonstrated improved performance from pre- to post-test. More specifically, the less able children who participated in an interactive session with a more capable peer were subsequently able to complete a relatively greater number of sorts with the attribute blocks compared to those children who worked individually, were paired with a child of similar ability or worked with a child of lower ability. This result provides support for the first hypothesis and is consistent with results Garton and Pratt (2001) obtained in a similar study.

Children who were instructed to provide explanations during the collaborative phase, were subsequently able to complete a relatively greater number of sorts of the attribute blocks from pre- to post-test compared to those children in dyads where there was minimal verbal interaction, and those children who worked independently. This result is supportive of research by Kruger (1992) and Teasley (1995), which indicated that the active exchange of ideas, rather than merely working together, was integral to improved performance. Further analysis, limited to low sorting ability children collaborating with higher sorting ability peers, showed that those children who were required to explain the sort for their partner to perform made significantly greater gains in sorting ability from pre- to post-test compared to those children where verbal interaction was minimal. This result provides support for the second hypothesis.

These findings suggest that although there is a performance output benefit for children working collaboratively, the longer-term cognitive benefit for individual children appears to be affected by a number of factors. It seems important that children are exposed to a higher level of reasoning than that which they exhibited at pre-test and that they accept this reasoning as valid. In addition, active participation and reasoned communication seem to be critical underlying factors. However, the generalisability and

durability of the cognitive change observed is an unknown factor and one requiring further study.

Arguably the improved performance of low ability children paired with a higher ability child supports Vygotsky's (1978) theory, which contended that cognitive change depended on social interaction with more "expert" others. From this perspective, the failure of children paired with a same or lesser ability child to improve significantly, as a group, could be attributed to their lack of exposure to information outside their initial level of competence. With no need to internalise new knowledge or construct new meaning there was a corresponding lack of cognitive change. The situation then is little different to exploring the task alone.

Yet this does not mean Piaget's (1959) theory should be dismissed. It could equally be argued that the cognitive conflict central to Piagetian theory was only present in those dyads where participants had different levels of sorting ability. Neither the materials nor the experimenter provided feedback. Consequently, children working with a same or lesser ability child, or individually, arguably did not enter a state of disequilibrium and hence the process of restoring equilibration, which is inherent to the Piagetian theory of cognitive change, did not occur.

Interaction with a more knowledgeable peer did not guarantee cognitive change, as not all low achievers paired with a higher achiever made positive gains in sorting ability. There could be several reasons for this. From a Vygotskian perspective, although the children may have had the same pre-test level of problem solving ability, they may have had different zones of proximal development. That is, the subsequently more successful child may have been developmentally ready to benefit from the interaction. Alternatively, the higher ability child may not have scaffolded effectively. For example, the experimenter observed that children did not routinely monitor their partner's sorts nor adapt their level of interaction to their partner's needs. Yarrow and

Topping (2001) and King, Staffieri and Adelgais (1998) have investigated elements of mutual peer scaffolding. However, given that limited resources often force teachers to use group work, it would be beneficial to determine the specific language and behavioural traits associated with effective peer scaffolding, and whether these skills could be successfully taught.

The nature of the relationship between the two partners may have contributed to different success levels. Tudge (1993) suggests that even though at pre-test one child may have demonstrated greater competence than another, if this level of thinking is not held with some degree of confidence then it is less likely that they will introduce higher levels of thinking into the discourse to aid their partner's thinking. He found that the degree of confidence children brought to the task was an important factor in the interaction. Although Piagetians may argue that peer interactions represent equality of status, it is likely that children themselves hold preconceived ideas of their own and their partner's competence. In fact, Azmitia (1988) found that even preschoolers in her study were aware of their own and other's relative competence. Where children perceive an uneven power and knowledge relationship, the pattern of interaction may be more akin to an adult-child relationship, resulting in passive acceptance of their partners' input without active engagement in cognitive restructuring. Future studies could consider the impact of children's perception of the relative competence of group members and how this influences the nature of the interaction and subsequent cognitive change.

This study highlights the importance of language in effective collaborative interactions. Collaborating without active verbal interaction was statistically no better than working independently. In addition, the experimenter observed that without language the tendency for turn taking was more evident. Children appeared less likely to watch, make sense of, or evaluate the correctness of their partner's sort. In comparison, the requisite of explaining a sort to a partner intrinsically resulted in the need for both

children to evaluate the explanation, explore and clarify inconsistencies or misunderstandings, elaborate ideas, link the verbal information to actual production, and to evaluate the success or otherwise of the activity through appropriate feedback. Teasely (1995) suggests that this type of verbalisation promotes the cognitive restructuring that underpins cognitive change.

Again this result can be interpreted both from a Piagetian and a Vygotskian perspective. From a Piagetian perspective interactions that are characterised by conflict and negotiation lead to greater cognitive gains. In the non-explanation condition, children did not have to confront differences in their own and their partner's problem solving behaviour. However, in the explanation condition, there was a need for children to convince themselves and their partner of the correctness of a particular sort. In addition, working with a peer may have provided children with a better understanding of the sorting process by formalising the important components of the problem-solving task and clarifying the experimenter's expectations.

Vygotskians see the value in language as a medium for discussing how to proceed and restructuring ideas in light of peers' more divergent and sophisticated range of sorting strategies. From this perspective, the explanation condition provided children with the opportunity to explore discrepancies between their own and their partner's knowledge, restructure their own knowledge and thinking, correct misconcepts, fill gaps in understanding and potentially develop new strategies for solving sorting problems.

It is often argued that the more knowledgeable children should benefit from collaboration since the process of explaining and clarifying are believed to make their ideas clearer and more explicit (see Teasley, 1995). Thus although there may be no obvious measurable improvement there may better understanding through consolidation. Yet in this study, even in the explanation condition, high achievers had a tendency to regress from pre to post test achievement.

The scope of this study was modest and consequently the results should be interpreted with caution. The study used an experimental paradigm in which peer collaboration occurred outside the classroom, during the course of a single period and limited to children attending schools classified in the highest socio-economic band. Investigating the cognitive benefits of peer collaboration over a long-term, within the classroom setting, and involving schools from a variety of socio-economic bands would increase the external validity of this current study. In addition, a comparative study between the effectiveness of peer collaboration and other types of instructional methods would throw further light onto the cognitive benefits of small group work.

This study did not take into consideration the personality traits and social skills that individual students brought to the interaction. Garton, Harvey and Pratt (2002) and Tudge, Winterhoff and Hogan (1996) suggest that child sociability and confidence may impact on the collaborative process. Thus social skills and personality traits may have been confounding variables. Further consideration could be given to these factors in future research.

This study has several implications for teachers. Simply assigning students to groups and telling them to work together will not necessarily promote co-operation or achievement. In the experimental condition, children often required prompting to ensure they adequately explained the sort to, and supported, their partner. Consequently, training children in interactive skills (such as providing explanations and being sensitive to other students' needs) may be a prerequisite of successful peer collaboration.

The tasks chosen for peer collaboration need to be appropriate to the capabilities of the individual learners and to the collaboration process, and structured so that children must work together co-operatively for successful completion. Integral to this process is the necessity for joint action and verbal explanations. In addition, groups should be constructed to include children with different skill levels or perspectives. Such an

approach would satisfy the Vygotskian condition of providing information within children's zones of proximal development and also create the socio-cognitive conflict necessary from a Piagetian perspective. But most importantly, these strategies would allow for the active participation and verbal interaction believed to underpin internal reorganisation and hence cognitive change.

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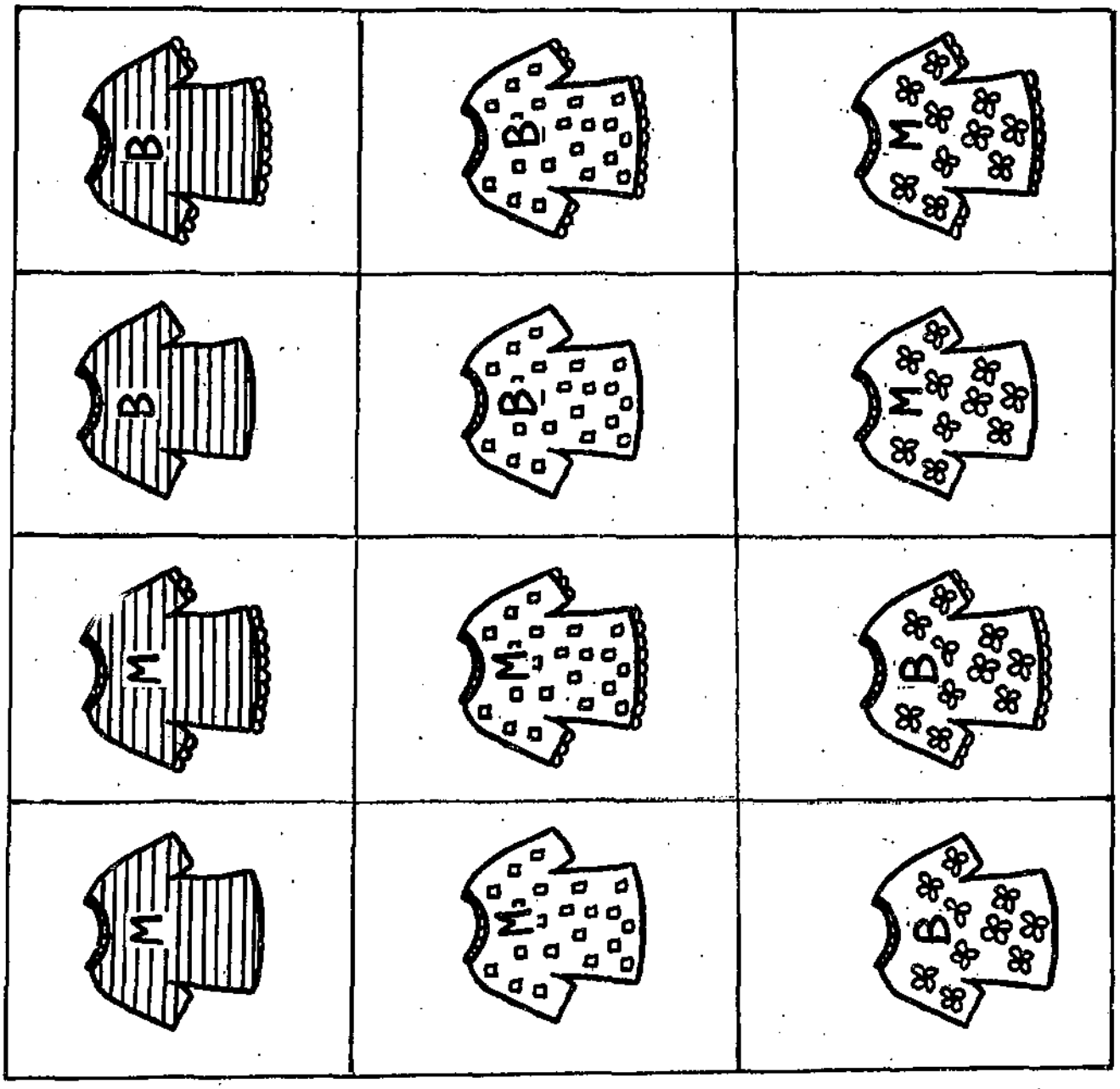
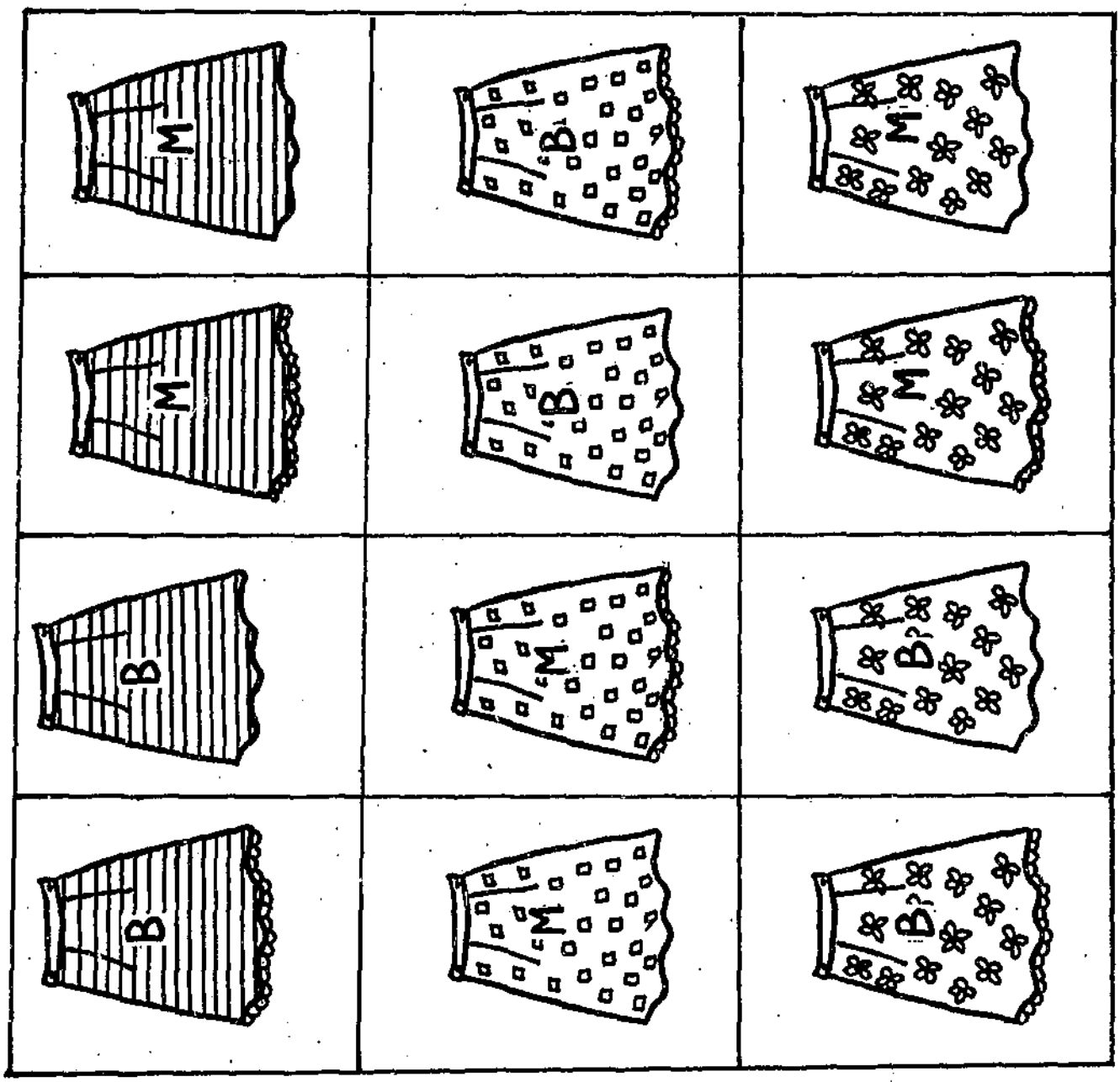
Appendix A

Sample of Clothing Cards

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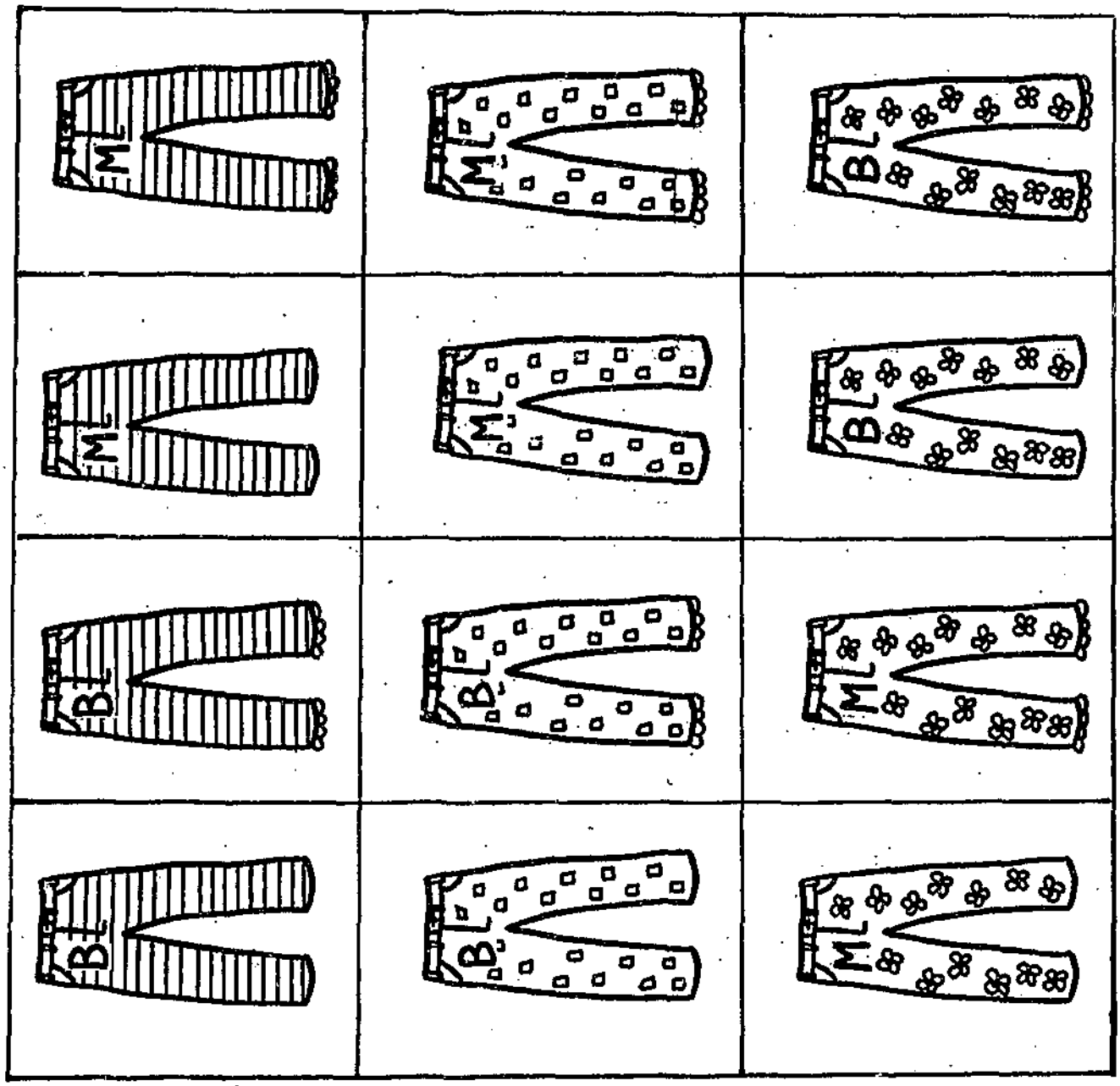
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Appendix B

Instructions for each condition

In the initial pre-test the children were provided with the following instructions:

> I have here, lots of different blocks. There are triangles, squares and circles. There are red blocks, yellow blocks and blue blocks. Some blocks are big and some are little. Some blocks are fat and some are thin. I want you to sort the blocks into piles. When you sort things, you have to put the blocks that are the same in some way, all together in one pile. Because there are lots of different things about these blocks, there are a lot of different ways to sort them. I want you to see how many different ways you can sort the blocks.

In the elaborate explanation condition children were provided with the following instructions:

> There are 14 different ways that these cards can be sorted. Working together, I want you to see how many different ways you can sort the cards? If you have an idea for sorting the cards you must explain your idea to your partner and your partner must follow your instructions to do the sort. You can ask your partner questions if you don't understand.

In the minimal verbal interaction condition, children were provided with the following instructions:

> There are 14 different ways that these cards can be sorted. Working together, I want you to see how many different ways you can sort the cards? I want you to work quietly so we don't disturb the other children, so please try not to talk. If you have an idea for sorting the cards, just pick them up and sort them to show your partner.

Children were dissuaded from talking through the use of a variety of non-verbal signals such as a touch on the arm, shake of the head, or finger to lips.

Children in the control groups were told that there were 14 different ways to sort the cards, however, they worked by themselves on the task.

Appendix C

Introductory Letter to Principals

Lillian Fawcett
72 Wessex Street
CARINE WA 6020
Ph: 9243 7193

The Principal
_____ Primary School
_____
_____ WA

May 22, 2002

Dear _____,

Re: Approval to conduct research at Rosalie Primary School

I am currently studying a Bachelor of Arts (Psychology) Honours, at Edith Cowan University. To complete the thesis component of my course I will be investigating the effect of collaborative learning activities on Year 2 children's problem solving ability under the supervision of Professor Alison Garton. The research proposal has approval from the Edith Cowan University Faculty Ethics Committee.

Peer based, small group activities are an integral part of many Western Australian classrooms. This project aims to determine some of the factors contributing to the successful use of this learning strategy. In particular it will investigate the extent to which working collaboratively with same age and gender peers enhances children's problem solving abilities and whether differences in knowledge status or the use of explanatory language has a mediating effect. It is hoped that the information obtained will assist teachers in the provision of effective learning environments for their students, particularly when using group work as a learning strategy.

The study comprises three tasks: an individually conducted pre- and post-test using a block sorting task which will each take a maximum of 10 minutes to complete; and a card sorting activity which children will complete in pairs (or individually if they are allocated to the control group) and takes a maxinum of 20 minutes. I will supervise all tasks. It is preferable that the tasks be completed in a separate room to, or an area outside, the classroom.

I will hold all information in strict confidence and once the data are converted to electronic form it will be coded and student names will be deleted from the primary records. In the final report, data will be provided in group form only. Children's raw scores on the pre- and post-test sorting task could be made available to yourself, classroom teachers, and/or the relevant child and his/her parents, on request.

This information could then be used to support children within the ongoing classroom programme.

Children's participation in the research would be totally voluntary and they would be free to withdraw at any time during the study, without penalty. In order for children to participate it would be necessary to obtain the consent of the classroom teacher and written permission from each child's parent. Please find attached a sample consent letter and an informed consent statement to be read to each child.

I have enclosed a copy of my research proposal, which provides more detailed information. However, if you have any questions concerning this project please contact myself on 9243 7193 or my supervisor Professor Alison Garton at the School of Psychology, Edith Cowan University on 9400 5110.

At the conclusion of the study, a copy of the final results will be available on request.

I hope you and your staff will be interested in participating in this action research and I look forward to hearing from you in the near future.

Yours sincerely,

Lillian Fawcett
B. Ed., MA (Psychology)

Introductory Letter to Parents/Guardians

Lillian Fawcett
72 Wessex Street
CARINE WA 6020

May, 2002

Dear Parents/Guardians,

I am currently studying a Bachelor of Arts (Psychology) Honours, at Edith Cowan University. To complete the thesis component of my course I will be investigating the effect of collaborative learning activities on Year 2 children's problem solving ability under the supervision of Professor Alison Garton. This research project has approval from the Edith Cowan University Faculty Ethics Committee. It has also been discussed with your school Principal and classroom teacher, who have indicated their willingness to be involved.

Peer based, small group activities are an integral part of many Western Australian classrooms. This project aims to help psychologists and teachers determine the factors that contribute to the successful use of this learning strategy. More specifically, this study will investigate the extent to which working collaboratively with same age and gender peers enhances children's problem solving abilities and whether differences in ability or level of communication has a mediating effect. This research is important as it is hoped that the information obtained may help teachers provide the most effective learning environment for their students, particularly when they are using group work as a learning strategy.

The study comprises three tasks: an individually conducted pre- and post-test using a block sorting task which will each take a maximum of 10 minutes to complete; and a card sorting activity which children will complete in pairs (or individually if they are allocated to the control group) and takes a maximum of 20 minutes. I will supervise all tasks, which will take place in a quiet space within the school buildings.

I will hold all information in strict confidence and once the data are converted to electronic form it will be coded and student names will be deleted from the primary records. In the final report, data will be provided in group form only. Children's raw scores on the pre- and post-test sorting task will be made available to the Principal and your child's classroom teacher so they can support your child within the ongoing classroom programme. You can also obtain your own child's score on request from the classroom teacher or me.

If you have any questions concerning this project please contact myself on 9243 7193 or my supervisor Professor Alison Garton at the School of Psychology, Edith Cowan University on 9400 5110.

Children participating in previous studies have found the task and process interesting and enjoyable. Your child's participation in the research would be totally voluntary and he/she would be free to withdraw at any time during the study, without penalty. If you consent to your child's participation in this research, please sign the attached consent form and return it to your child's teacher as soon as possible.

Yours sincerely,

Lillian Fawcett
B. Ed., MA (Psychology)

Parent/Guardian Consent Form

Project Title: The effect of collaborative learning on children's problem solving.

I _____ (the parent/guardian of the participant) have read and understood the information provided with this consent form and any questions I have asked have been answered to my satisfaction.

I agree to allow my child _____ (name) to participate in the activities associated with this research and I understand that I, or my child, can withdraw consent at any time.

I agree that the research data gathered in this study may be published, provided my child and my child's school is not identifiable in any way.

_____ _____

Parent/Guardian's Signature Date

If you require further information about this project please contact Lillian Fawcett (Ph: 9243 7193) or Professor Alison Garton, School of Psychology, Edith Cowan University (Ph: 9400 5110). If you wish to contact someone, who is independent of the research project, about the study, please contact Dr Craig Speelman, Head of School (Psychology), Edith Cowan University (Ph: 9400 5724).

Child Verbal Consent

(To be read to child participants)

My name is Lillian Fawcett and I am studying psychology at Edith Cowan University. I am doing an experiment to study how children work together to solve problems and I would like you to participate in the experiment.

There are three parts to the experiment. First, I will ask you to sort some blocks by yourself. That will take about 10 minutes. Then I will come back another day and I will ask you to work with a partner to sort some cards for about 20 minutes. And then I will come back the next week and ask you to sort the blocks again by yourself.

Your participation in this experiment is voluntary. That means if you don't want to do the activity, you don't have to. It also means that you can stop at any time during the experiment and this is okay – it won't be a problem and you won't get into trouble.

Have you got any questions you would like to ask me about the experiment?

Would you like to be in the experiment?

Appendix D

Data Variable Key

Column Label	**Variable**
Gender	1=male 2=female
Age	Years and months
Pretest	Number of correct sorts of the attribute blocks obtained during the pre-test by each individual child
Pretime	Time spent sorting attribute blocks during the pre-test
Ability	1=high (5 or more correct sorts) 2=low (0-4 correct sorts)
Group	1=low ability paired with low ability 2=low ability paired with high ability 3=high ability paired with low ability 4=high ability paired with high ability 5=low ability working individually (control) 6=high ability working individually (control)
Talk	1=elaborate explanations 2=minimal verbal interaction 3=control (working individually)
Expscore	Total number of correct sorts of the clothing cards achieved by the child and his/her partner
Exptime	Time spent sorting the clothing cards during the experimental phase.
Posttest	Number of correct sorts of the attribute blocks obtained during the post-test by each individual child
Posttime	Time spent sorting attribute blocks during the pre-test
Diff	Difference between the pre- and post-test scores

	gender	age	pretest	pretime	ability	group	talk	expscore	exptime	posttest	posttime	diff
1	1	7.00	4	9.13	1	1	1	6	17.39	4	8.08	0
2	2	7.04	4	4.23	1	1	1	6	20.27	5	6.29	1
3	1	7.04	7	16.23	2	3	1	5	16.12	6	14.16	-1
4	2	7.08	3	5.32	1	2	1	11	30.32	5	9.58	2
5	1	7.00	3	4.38	1	2	1	5	16.12	8	15.37	5
6	2	6.06	3	4.06	1	1	2	7	24.43	2	5.43	-1
7	1	7.04	5	9.45	2	4	2	9	22.01	4	7.19	1
8	1	6.09	4	4.42	1	1	1	6	17.39	5	4.46	1
9	1	7.08	5	6.10	2	4	2	9	22.01	6	8.01	1
10	2	6.07	4	10.26	1	5	3	5	9.06	3	5.19	-1
11	2	7.04	7	9.34	2	3	1	11	30.32	9	11.45	2
12	2	6.09	8	13.14	2	3	2	8	20.15	6	10.19	-2
13	2	6.06	3	2.07	1	1	2	7	24.43	5	7.06	2
14	1	7.00	5	8.56	2	4	1	6	24.00	5	9.51	0
15	1	6.07	3	6.45	1	1	2	5	12.05	4	4.50	1
16	1	7.00	3	4.24	1	1	2	5	12.05	3	3.50	0
17	1	7.09	5	7.15	2	4	1	6	24.00	5	7.38	0
18	2	6.11	4	10.05	1	1	1	6	20.27	3	3.18	-1
19	2	7.04	4	8.28	1	2	2	7	22.03	4	8.27	0
20	2	7.05	3	8.27	1	5	3	6	19.13	4	7.52	1
21	2	7.00	9	14.45	2	3	2	7	22.03	9	19.32	0
22	2	7.03	4	3.58	1	2	2	8	20.15	4	7.03	0
23	2	6.09	5	6.37	2	6	3	7	10.45	5	7.15	0
24	1	6.10	5	6.41	2	6	3	6	11.41	4	7.17	-1
25	2	7.02	3	3.53	1	2	1	8	17.13	4	5.29	1

	gender	age	pretest	pretime	ability	group	talk	expscore	exptime	posttest	posttime	diff
26	2	7.03	2	3.13	1	2	1	10	27.53	4	3.30	2
27	2	7.02	4	6.01	1	1	2	4	9.35	4	3.59	0
28	2	6.10	7	16.18	2	3	1	8	17.13	6	9.16	-1
29	2	6.08	6	10.09	2	3	1	10	27.53	6	10.19	0
30	1	7.04	6	7.02	2	3	1	8	28.53	7	11.14	1
31	1	6.08	3	5.29	1	2	2	5	14.12	3	6.45	0
32	1	6.10	1	3.15	1	2	2	6	13.42	2	5.15	1
33	1	7.04	6	10.08	2	3	2	5	14.12	4	8.48	-2
34	1	6.09	0	1.25	1	5	3	2	3.39	0	2.32	0
35	1	7.04	3	4.48	1	5	3	4	7.35	4	7.54	1
36	2	7.03	3	4.48	1	5	3	4	5.45	3	2.46	0
37	1	7.01	3	8.21	1	1	1	4	7.30	4	7.33	1
38	1	6.07	5	7.10	2	3	2	6	13.42	5	7.34	0
39	2	7.02	5	12.22	2	6	3	6	19.30	6	8.41	1
40	2	7.07	4	7.40	1	1	2	4	9.35	4	5.08	0
41	1	6.11	3	3.55	1	2	1	8	28.53	4	4.28	1
42	1	7.03	3	5.48	1	1	1	4	7.30	4	4.04	1
43	2	6.10	5	7.59	2	3	2	5	14.43	4	6.54	1
44	2	6.04	7	12.28	2	3	1	6	17.39	6	10.00	-1
45	2	6.08	4	4.56	1	2	1	6	17.39	4	6.38	0
46	2	7.07	3	6.46	1	1	1	4	8.09	3	3.53	0
47	2	6.11	3	5.23	1	1	1	4	8.09	3	5.24	0
48	2	7.04	2	5.21	1	2	2	5	14.43	4	10.07	2
49	2	7.00	2	3.29	1	1	1	5	10.30	3	3.30	1
50	1	6.10	3	4.42	1	2	1	7	18.48	4	6.54	1

	gender	age	pretest	pretime	ability	group	talk	expscore	exptime	posttest	posttime	diff
51	1	7.04	2	6.54	1	5	3	4	14.21	2	5.38	0
52	1	7.06	3	5.25	1	1	2	4	7.28	2	2.49	-1
53	1	6.05	7	6.47	2	3	1	7	18.48	7	15.30	0
54	1	6.10	3	8.12	1	5	3	3	5.50	3	6.13	0
55	1	7.03	4	8.38	1	5	3	4	5.55	3	5.48	-1
56	1	7.00	3	5.02	1	1	2	4	7.28	3	3.15	0
57	1	7.02	4	4.40	1	2	2	7	13.04	5	9.32	1
58	2	7.02	2	4.04	1	1	1	5	10.30	3	3.43	1
59	1	7.04	7	10.16	2	3	2	7	13.04	6	10.50	1
60	2	7.05	3	6.07	1	5	3	3	5.30	4	5.09	1
61	2	7.03	4	4.58	1	5	3	2	3.24	3	5.31	-1
62	2	6.08	5	5.58	2	6	3	4	10.46	4	7.30	-1
63	1	7.02	5	9.53	2	6	3	4	8.54	5	7.49	0
64	1	6.10	4	4.44	1	1	2	5	12.41	4	4.01	0
65	1	7.02	4	3.59	1	1	2	5	12.41	4	4.34	0
66	2	6.08	6	9.43	2	4	1	5	13.43	5	10.35	-1
67	2	7.02	5	10.10	2	4	1	5	13.43	5	10.02	0
68	1	6.06	5	10.21	2	4	2	6	14.43	4	4.49	-1
69	1	7.03	5	10.24	2	4	2	6	14.43	6	8.55	1
70	1	6.09	6	9.06	2	6	3	6	12.38	6	8.23	0
71	2	6.10	9	14.12	2	3	2	7	20.48	9	13.26	0
72	1	6.10	3	8.16	1	2	1	9	30.30	6	12.10	3
73	1	7.02	5	8.38	2	4	1	6	19.09	5	5.31	0
74	2	7.01	5	8.37	2	4	2	5	14.26	5	8.25	0
75	1	7.04	6	8.52	2	6	3	4	12.38	5	8.02	-1

	gender	age	pretest	pretime	ability	group	talk	expscore	exptime	posttest	posttime	diff
76	2	6.09	5	5.14	2	4	2	5	14.26	4	5.50	-1
77	2	7.00	4	8.43	1	2	2	7	20.48	4	6.53	0
78	1	7.04	5	9.06	2	4	1	6	19.09	5	9.50	0
79	1	7.06	7	11.17	2	3	1	9	30.30	8	12.29	1
80	2	7.03	7	10.00	2	6	3	10	21.06	6	11.16	-1
81	1	7.04	6	10.31	2	6	3	5	17.11	6	6.47	0
82	2	7.01	3	4.36	1	2	2	8	21.31	5	7.13	2
83	1	7.04	6	11.06	2	4	1	8	18.54	7	9.13	1
84	1	7.01	6	7.33	2	4	1	8	18.54	5	6.24	-1
85	2	6.10	3	5.56	1	✓ 2	1	8	17.21	6	8.27	3
86	1	6.06	5	11.12	2	4	2	5	15.11	4	4.16	-1
87	1	7.02	3	4.32	1	2	2	7	19.43	4	3.41	1
88	1	6.06	3	4.49	1	2	2	8	21.31	3	3.41	0
89	1	6.07	6	4.49	2	3	2	8	21.31	6	7.50	0
90	2	7.01	5	7.57	2	4	1	7	17.31	5	6.29	0
91	2	7.06	6	7.03	2	3	2	8	17.53	5	5.51	-1
92	2	7.02	5	7.03	2	4	1	7	17.31	5	5.07	0
93	1	7.03	5	7.21	2	4	2	5	15.11	5	7.56	0
94	1	6.07	2	4.54	1	✓ 2	1	8	24.08	5	8.39	3
95	2	6.06	5	9.48	2	4	2	8	17.34	5	6.40	0
96	1	7.00	8	11.20	2	3	1	8	24.08	8	10.50	0
97	2	6.11	5	5.25	2	4	2	8	17.34	5	3.22	0
98	2	6.11	6	7.13	2	3	1	5	17.21	6	5.40	0
99	1	7.07	6	9.01	2	3	2	7	19.43	7	8.21	1
100	2	7.02	6	6.56	2	6	3	8	15.31	6	5.27	0

Appendix E

Statistical Analysis of Data

UNIVARIATE ANALYSIS OF VARIANCE:
Comparison of Ability groups and talk/no talk conditions

Between-Subjects Factors

		Value Label	N
group	1	low/low	20
	2	low/high	20
	3	high/low	20
	4	high/high	20
	5	control/low	10
	6	control/high	10
talk	1	talk	40
	2	no talk	40
	3	control	20

Descriptive Statistics

Dependent Variable: pre-post diff

group	talk	Mean	Std. Deviation	N
low/low	talk	.50	.71	10
	no talk	.10	.88	10
	Total	.30	.80	20
low/high	talk	2.10	1.45	10
	no talk	.70	.82	10
	Total	1.40	1.35	20
high/low	talk	.10	.99	10
	no talk	-.20	1.14	10
	Total	-5.00E-02	1.05	20
high/high	talk	-.10	.57	10
	no talk	3.15E-17	.82	10
	Total	-5.00E-02	.69	20
control/low	control	1.05E-17	.82	10
	Total	1.05E-17	.82	10
control/high	control	-.30	.67	10
	Total	-.30	.67	10
Total	talk	.65	1.29	40
	no talk	.15	.95	40
	control	-.15	.75	20
	Total	.29	1.10	100

Levene's Test of Equality of Error Variances[a]

Dependent Variable: pre-post diff

F	df1	df2	Sig.
1.442	9	90	.182

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept+GROUP+TALK+GROUP * TALK

Tests of Between-Subjects Effects

Dependent Variable: pre-post diff

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	44.690[a]	9	4.966	5.888	.000
Intercept	5.066	1	5.066	6.007	.016
GROUP	28.750	4	7.188	8.523	.000
TALK	5.000	1	5.000	5.929	.017
GROUP * TALK	6.100	3	2.033	2.411	.072
Error	75.900	90	.843		
Total	129.000	100			
Corrected Total	120.590	99			

a. R Squared = .371 (Adjusted R Squared = .308)

Multiple Comparisons

Dependent Variable: pre-post diff

Tukey HSD

(I) talk	(J) talk	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
talk	no talk	.50*	.21	.044	1.06E-02	.99
	control	.80*	.25	.006	.20	1.40
no talk	talk	-.50*	.21	.044	-.99	-1.06E-02
	control	.30	.25	.460	-.30	.90
control	talk	-.80*	.25	.006	-1.40	-.20
	no talk	-.30	.25	.460	-.90	.30

Based on observed means.

*. The mean difference is significant at the .05 level.

Multiple Comparisons

Dependent Variable: pre-post diff

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
low/low	low/high	-1.10*	.29	.004	-1.95	-.25
	high/low	.35	.29	.833	-.50	1.20
	high/high	.35	.29	.833	-.50	1.20
	control/low	.30	.36	.958	-.74	1.34
	control/high	.60	.36	.544	-.44	1.64
low/high	low/low	1.10*	.29	.004	.25	1.95
	high/low	1.45*	.29	.000	.60	2.30
	high/high	1.45*	.29	.000	.60	2.30
	control/low	1.40*	.36	.002	.36	2.44
	control/high	1.70*	.36	.000	.66	2.74
high/low	low/low	-.35	.29	.833	-1.20	.50
	low/high	-1.45*	.29	.000	-2.30	-.60
	high/high	6.94E-18	.29	1.000	-.85	.85
	control/low	-5.00E-02	.36	1.000	-1.09	.99
	control/high	.25	.36	.981	-.79	1.29
high/high	low/low	-.35	.29	.833	-1.20	.50
	low/high	-1.45*	.29	.000	-2.30	-.60
	high/low	-6.94E-18	.29	1.000	-.85	.85
	control/low	-5.00E-02	.36	1.000	-1.09	.99
	control/high	.25	.36	.981	-.79	1.29
control/low	low/low	-.30	.36	.958	-1.34	.74
	low/high	-1.40*	.36	.002	-2.44	-.36
	high/low	5.00E-02	.36	1.000	-.99	1.09
	high/high	5.00E-02	.36	1.000	-.99	1.09
	control/high	.30	.41	.978	-.90	1.50
control/high	low/low	-.60	.36	.544	-1.64	.44
	low/high	-1.70*	.36	.000	-2.74	-.66
	high/low	-.25	.36	.981	-1.29	.79
	high/high	-.25	.36	.981	-1.29	.79
	control/low	-.30	.41	.978	-1.50	.90

Based on observed means.

*. The mean difference is significant at the .05 level.

UNIVARIATE ANALYSIS OF VARIANCE:
Comparison of Dyads and Individuals

Between-Subjects Factors

		Value Label	N
control/exp	1	experimental	80
	2	control	20

Descriptive Statistics

Dependent Variable: experimental score

control/exp	Mean	Std. Deviation	N
experimental	6.54	1.70	80
control	4.85	1.98	20
Total	6.20	1.87	100

Levene's Test of Equality of Error Variances[a]

Dependent Variable: experimental score

F	df1	df2	Sig.
.201	1	98	.655

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept+CONTROL

Tests of Between-Subjects Effects

Dependent Variable: experimental score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	45.563[a]	1	45.563	14.764	.000
Intercept	2074.803	1	2074.803	672.306	.000
CONTROL	45.562	1	45.562	14.764	.000
Error	302.437	98	3.086		
Total	4192.000	100			
Corrected Total	348.000	99			

a. R Squared = .131 (Adjusted R Squared = .122)

UNIVARIATE ANALYSIS OF VARIANCE:
Low ability collaborating with high ability children in talk vs no talk conditions

Between-Subjects Factors

		Value Label	N
highlow	1	talk	10
	2	no talk	10

Descriptive Statistics

Dependent Variable: pre-post diff

highlow	Mean	Std. Deviation	N
talk	2.10	1.45	10
no talk	.70	.62	10
Total	1.40	1.35	20

Levene's Test of Equality of Error Variances[a]

Dependent Variable: pre-post diff

F	df1	df2	Sig.
2.101	1	18	.164

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept+HIGHLOW

Tests of Between-Subjects Effects

Dependent Variable: pre-post diff

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9.800[a]	1	9.800	7.056	.016
Intercept	39.200	1	39.200	28.224	.000
HIGHLOW	9.800	1	9.800	7.056	.016
Error	25.000	18	1.389		
Total	74.000	20			
Corrected Total	34.800	19			

a. R Squared = .282 (Adjusted R Squared = .242)

Appendix F

British Journal of Developmental Psychology

Notes for Contributors

The *British Journal of Developmental Psychology* aims to publish full length, empirical, conceptual, review and discussion papers, as well as brief reports in the following areas:

- Development during childhood and adolescence;
- Early infant perceptual, cognitive and motor development;
- Abnormal development - the problems of handicaps, learning difficulties and childhood autism;
- Education implications of child development;
- Parent-child interaction;
- Social and moral development;
- Effects of ageing.

1. Circulation

1. The circulation of the Journal is worldwide. There is no restriction to British authors; papers are invited and encouraged from authors throughout the world.

2. Length

Pressure on Journal space is considerable and papers should be as short as is consistent with clear presentation of the subject matter. Papers should normally be no more than 5,000 words, although the Editor retains discretion to publish papers beyond this length.

3. Refereeing

The journal operates a policy of anonymous peer review. Papers will normally be scrutinised and commented on by at least two independent expert referees (in addition to the Editor) although the Editor may process a paper at his or her discretion. The referees will not be made aware of the identity of the author. All information about authorship including personal acknowledgements and institutional affiliations should be confined to a removable front page (and the text should be free of such clues as identifiable self-citations ('In our earlier work...')).

4. Submission requirements

- Four copies of the manuscript should be sent to the Editor (Professor Gavin Bremner, BPS Journals Department, St. Andrews House, 48 Princess Road East, Leicester, LE1 7DR, UK). Submission of a paper implies that it has not been published elsewhere and that it is not being considered for publication in another journal. Papers should be accompanied by a signed letter indicating that all named authors have agreed to the submission. One author should be identified as the correspondent and that person's title, name and address supplied.

- Contributions must be typed in double spacing with wide margins and on only one side of each sheet. All sheets must be numbered.
- Tables should be typed in double spacing, each on a separate piece of paper with a self-explanatory title. Tables should be comprehensible without reference to the text. They should be placed at the end of the manuscript with their approximate locations indicated in the text.
- Figures are usually produced direct from authors' originals and should be presented as good black or white images preferably on high contrast glossy paper, carefully labelled in initial capital/lower case lettering with symbols in a form consistent with text use. Unnecessary background patterns, lines and shading should be avoided. Paper clips leave damaging indentations and should be avoided. Any necessary instructions should be written on an accompanying photocopy. Captions should be listed on a separate sheet.
- All articles should be preceded by an Abstract of up to 300 words, giving a concise statement of the intention and results or conclusions of the article.
- Bibliographic references in the text should quote the author's name and the date of publication thus: Smith (1994). Multiple citations should be given alphabetically rather than chronologically: (Jones, 1998; King, 1996; Parker, 1997). If a work has two authors, cite both names in the text throughout: Page and White (1995). In the case of reference to three or more authors, use all names on the first mention and et al. thereafter except in the reference list.
- References cited in the text must appear in the list at the end of the article. The list should be typed in double spacing in the following format:
- Herbert, M. (1993). *Working with children and the Children Act (*pp. 76-106). Leicester: The British Psychological Society.
- Samuels, M.C., Brooks, P.J., & Frye, D. (1996). Strategic game playing in children through the windows task. *British Journal of Developmental Psychology*, 14, 159-172.
- Particular care should be taken to ensure that references are accurate and complete. Give all journal titles in full.
- SI units must be used for all measurements, rounded off to practical values if appropriate, with the Imperial equivalent in parentheses (see British Psychological Society Style Guide at http://www.bps.org.uk/publications/jAuthor.cfm).
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- Authors are responsible for acquiring written permission to publish lengthy quotations, illustrations etc for which they do not own copyright.

5. E-mail and Web submissions

Manuscripts may also be submitted via e-mail and the BPS Website (http://.www.bps.org.uk/publication/jsubmissions.cfm). The main text of the manuscript, including any tables or figures, should be saved as a Word 6.0/95 compatible file. The file must be sent as a MIME-compatible attachment. E-mails should be addressed to journals@bps.org.uk with 'Manuscript submission' in the subject line. The main body of the e-mail should include the following: title of journal to which the paper is being submitted; name, address and e-mail of the corresponding author; and a statement that the paper is not currently under consideration elsewhere. Submissions will receive an e-mail acknowledgement of receipt.

6. Brief reports

Brief reports should be limited to 2,000 words or the equivalent in tables and text. The title should indicate exactly but as briefly as possible the subject of the article. Papers will be evaluated by the Editor and referees in terms of their theoretical interest, practical interest, relevance to the Journal and readability.

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8. Supplementary data

Supplementary data too expensive for publication may be deposited with the British Library Document Supply Centre. Such material includes numerical data, computer programs, fuller details of case studies and experimental techniques. The material should be submitted to the Editor together with the article, for simultaneous refereeing.

9. Proofs

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11. Checklist of requirements:

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- Correspondent's title/name/address
- A cover page with title/author(s)/affiliation
- Double spacing with wide margins
- Tables/figures at the end
- Complete reference list in APA format
- Four good copies of the manuscript (or an e-mail attachment)