

When Training With a Partner Is Inferior to Training Alone: The Importance of Dyad Type and Interaction Quality

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Dyad training, where trainees learn in pairs but ultimately perform individually, has been shown to be an effective method for training some skills. The effectiveness of this approach, however, may be tied to the type of task to be trained and the quality of the interaction in the dyad. We report two studies on the effectiveness of dyad training and the role of metacognitive activity for learning a software program. In Study 1, participants completed training alone or with a partner. Performance was assessed individually immediately after training and again after a 1-week nonuse interval. Results of Study 1 suggested that learning retention is superior when people are trained individually. Study 2 examined performance for individuals, task-switching dyads, and interdependent dyads. Results also showed that performance for individuals was superior to dyads and that the type of dyad collaboration did not affect performance. However, partner-prompted metacognitive activity was helpful for interdependent dyads and harmful for task-switching dyads, suggesting that the quality of collaboration varies by dyad type. Our findings suggest that dyad training may not be effective for all types of tasks. Possible boundary conditions for effective dyad training are discussed.

Keywords: training, dyad training, skill acquisition, metacognition

Training in today's ever-changing work environment has become increasingly important. As job responsibilities morph rapidly with technological advances, companies must provide training to employees at all levels to keep up. Such demands have sparked interest in collaborative training, as collaboration can increase efficiency (Shebilske, Regian, Arthur, & Jordan, 1992) and provide social benefits (Kraiger, 2008). Dyad training is one such form of collaborative training. In dyad training, two trainees work together to learn a new task that is intended to be performed on an individual basis. It is distinct from team-based training, which may focus on tasks that distribute essential information among group members so that they can only be completed when the members work together (see Kirschner, Paas, & Kirschner, 2009). Learning a new task with another person occurs in applied settings both by design, as when two new employees are assigned to work with one another, and as a result of circumstance, as when there are not enough computers available in a classroom and two students are asked to share a workstation. Will two trainees working together on a new task learn as much as one that learns alone? Some studies have shown that training with a partner (i.e., in dyads) is as effective as training individually even when the trainees will be

required to complete the task without a partner after training (Day, Arthur, & Shebilske, 1997; Shebilske et al., 1992). Relatively little research has been done, however, to determine the parameters within which dyad training is effective (although see Dillenbourg, Baker, Blaye, & O'Malley, 1996, for a review of collaborative learning with children). For example, what kinds of tasks can be trained in dyads without resulting in performance decrements once the learner must perform the task alone? Prior studies of dyad training have used tasks with heavy psychomotor components (Arthur, Day, Bennett, McNelly, & Jordan, 1997) or physical components (Shea, Wulf, & Whitacre, 1999). Although researchers working in this area have raised questions about the tasks for which dyad training would be effective (e.g., Shebilske, Jordan, Goettl, & Paulus, 1998), they have not empirically examined the effectiveness of dyad training for tasks that include a heavy declarative knowledge component (e.g., such as computer software training common in corporate environments). These prior studies have also not examined the quality of the interaction between dyad partners. The purpose of the current studies is to expand our understanding of when training with a partner is appropriate by exploring the boundary conditions for using dyad training.

Two studies are reported here that investigate the effectiveness of dyad training for a computer software program. In Study 1, individual performance for those trained in dyads is compared with those trained individually to determine if findings from previous research (Shebilske et al., 1992) will generalize to a task more dependent on declarative knowledge. Study 2 was designed to explore the effectiveness of different types of dyads to provide further insight into the type of collaboration that may be necessary to maximize performance in dyad training. These studies are framed within social learning theory (Bandura, 1977) and theories of skill acquisition (Ackerman, 1988; Anderson, 1982).

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Social Learning Theory

Bandura (1977) argued that virtually all learning is inherently social as humans can learn vicariously by seeing others' behaviors and the consequences that follow. Observational learning, however, is not merely automatic and passive imitation of others' behaviors. During observational learning, a learner must attend to important features of the behavior, retain the information in symbolic form in memory, and then adjust his or her behaviors as necessary when trying to reproduce the actions and outcome (Bandura, 1977). Although imitation is the reproduction of exact actions, modeling behavior based on observation means that the learner acquires general rules, which allow for variant forms of behavior (Bandura, 1986). This implies that observing behaviors that lead to undesirable outcomes does not mean that the observer is bound to repeat the same mistakes, as modeling is not pure imitation; on the contrary, observers can learn what errors to avoid by attending to the model's actions and resulting negative outcomes. Social learning theory, then, suggests that collaborative training can provide benefits for learning a complex task even if the learners are both novices and commit errors during the training process. Partners should be able to learn from one another through observation, provided that trainees attend to their partner's actions, retain the information in memory, and receive feedback on the consequences of those actions.

Prior work in dyad training has also been framed within social learning theory and found that observational learning is a key component to successfully supporting learning in a complex task (Shebilske, Jordan, Goettl, & Day, 1999; Shebilske et al., 1998). Although observation alone was not sufficient for learning in these studies, it provided a significant increase in performance compared to a control group. Pairing observational learning with direct hands-on practice allowed dyad trainees to perform as well as individual trainees on a complex task with large psychomotor skill components. To understand how dyad training may function in a task with a heavy declarative knowledge component, we next consider theories of skill acquisition and self-regulation in the early phases of learning.

Skill Acquisition and Self-Regulation

Anderson (1982) proposed a theory of skill acquisition defined by three phases of learning: declarative, knowledge compilation, and procedural. The theory states that, initially, a learner must acquire the basic knowledge and facts about a skill. During this declarative stage, the information required to perform the task is only known at a factual level, and these facts must be rehearsed and actively recalled by the learner. Performing the skill is done in an effortful step-by-step process. As the learner enters the knowledge compilation phase, the steps begin to group together as larger units of procedures and can be chunked without consideration of the individual steps. Finally, after sufficient practice, the learner reaches the procedural knowledge phase where performance becomes more routine and rapid.

Ackerman's (1988) theory of the cognitive correlates of skill acquisition posits that performance at each of the distinct phases of skill acquisition is predicated on different abilities. In the declarative stage, when performance is effortful and requires controlled processing, performance is most highly related to general cognitive

ability. During the knowledge compilation phase, perceptual speed ability (which is the ability to process cognitive information quickly and accurately; Ackerman, Beier, & Boyle, 2002) becomes more important for performance. Finally, during the procedural stage, psychomotor ability (defined as response speed for tasks requiring little or no information processing; Ackerman & Cianciolo, 1999) becomes increasingly related to performance. Ackerman's (1988) and Anderson's (1982) theories state that for skills that cannot be proceduralized (e.g., variably mapped tasks, Schneider & Shiffrin, 1977) learners will remain at the declarative knowledge or knowledge compilation phase for the duration of task performance.

Similarly, resource allocation theory (Kanfer & Ackerman, 1989) suggests that, when people are in the early phases of skill acquisition, processing is effortful and requires the focus of all attentional resources (i.e., cognitive ability). In the context of dyad training, in the early stages of skill acquisition for a proceduralized task, or for a skill that cannot be proceduralized, attentional resources must be fully devoted to practicing and/or observing one's partner practicing the skills. Some prior studies in dyad training have suggested that having a partner's input in training can help the learner focus their attention on learning parts of the task within the context of the whole (Arthur et al., 1995), thereby benefitting dyad trainees by reducing the attentional demands of the task. Another interpretation, however, includes consideration of the dyad interactions that may occur while engaging in this effortful processing of the declarative knowledge phase. Interaction with one's partner may facilitate learning (e.g., if an observer points out a mistake and both partners learn from the exchange). Some partner interactions, however, may not be beneficial and may actually detract attention from executing the skill and/or observing the actor executing the skill.

Of course, interactions that are off-task distract from the content to be learned and would be particularly problematic for people in the early phases of learning. Interactions that are on-task may also be disruptive, though. Collaborative inhibition is defined as decreased performance that results from working in a group compared with working alone (Basden, Basden, Bryner, & Thomas, 1997; Weldon & Bellinger, 1997).¹ Basden and colleagues (1997) suggested that people use idiosyncratic retrieval strategies to recall a list of words. The planned retrieval order is disrupted by the intrusion of a partner's responses, leading to a less effective and more disorganized retrieval of list items. In skill acquisition, a similar effect could occur as learners may lose their place in the skill sequence when their dyad partner interrupts them with questions or suggestions on how to proceed. During the initial learning process of a complex task, such interruptions are hypothesized to be particularly negative because attentional resources need to be focused on properly acquiring the skill (Kanfer & Ackerman, 1989).

In summary, the collaboration required for dyad training involves two components that may differentially affect performance: observational learning (i.e., modeling) and the interaction between dyad partners. If the interaction between partners is not ideal, dyad training may not be effective. Interference from a dysfunctional interaction will be especially problematic when the task to be

¹ We thank the Editor for suggesting this reference.

learned requires focused attentional resources over an extended period of time, such as performance on complex skills when performance is highly predicated on declarative knowledge.

Interactions between partners in a training situation are likely to be conducive to learning if they successfully prompt the same self-regulatory processes that facilitate learning for individuals. Metacognition has been shown to be positively related to individual training outcomes (Ford, Smith, Weissbein, Gully, & Salas, 1998; Schmidt & Ford, 2003). Below we review this research and discuss how metacognitive prompting in dyad training may facilitate learning in dyad training.

Metacognitive Activity

Metacognition is defined as the knowledge and control of one's cognitive processes (Eysenck & Keane, 2005; Flavell, 1979). Engaging in metacognitive activity includes monitoring one's learning progress, assessing the appropriateness of learning strategies, and determining how to spend one's time and cognitive resources on task mastery. Previous studies have demonstrated that self-reported metacognitive activity is positively related to both immediate and delayed test performance (Ford et al., 1998; Schmidt & Ford, 2003). Metacognition in these studies (Ford et al., 1998; Schmidt & Ford, 2003) has been investigated in individual learning situations.

Metacognitive monitoring is also potentially important in dyad training because the interaction between learners can contribute or detract from a learner's monitoring processes. For example, partners can prompt each others' metacognitive monitoring by asking questions about why certain actions are taken, or discussing why certain results are obtained. There is some evidence in collaborative research with children that providing explanations to teammates and discussing decision making steps can lead to better learning outcomes (Dillenbourg et al., 1996). If a partner's explanations or questions are posed at appropriate times and assist the learner in reflecting upon their actions, partner-prompted metacognition should be positively related to learning. Similarly, partners can detract from metacognitive monitoring when discussions are not relevant to the training task, are ill-timed, or poorly received by the training partner (i.e., seen as criticism). As such, the quality of the interaction between partners, operationalized here by the degree to which a partner prompted metacognition in the learner, will influence learning outcomes in dyad training.

Prior Research on Dyad Training

Prior studies in dyad training have shown that training complex skills in dyads can be as effective as training individually (Day et al., 1997; Shebilske et al., 1992). Shebilske et al. (1992) originally developed the active interlocked model (AIM) for training in dyads. The protocol was designed to allow two partners to learn an aviation video-game (Space Fortress; Mané & Donchin, 1989) originally designed for one person by separating a complex task into two distinct parts: flying a ship that shoots missiles (using a joystick) and managing mine detection and ammunition (using a mouse). In these studies, dyad partners each controlled one part of the task (either joystick or mouse) and alternated which part they controlled between practice trials. Individual trainees, in contrast, controlled both parts of the task during training. As such, trainees

in the dyad condition received only half of the amount of direct practice that individuals received. On later tests of performance, when all subjects were required to perform the whole task individually, subjects trained in dyads performed similarly to those who were trained individually. As there were no significant differences found in performance, Shebilske et al. (1992) concluded that dyad training using the AIM protocol is as effective as individual training. These findings have resulted in training changes for U.S. Air Force navigators and Aer Lingus airline pilots (see Shebilske et al., 1998 for a summary of applications).

Several replications of the AIM protocol in Space Fortress have been conducted (Arthur et al., 1997; Day et al., 1997). To explore the potential mechanisms through which AIM protocol partners learn, Shebilske and colleagues (Shebilske et al., 1998, 1999) investigated the effects of observational learning versus direct practice with the task. The results demonstrated that observational learning in dyads was beneficial but not sufficient for learning to be equivalent to training individually: The combination of half direct practice and half observation in AIM dyads was needed to achieve performance similar to individual training with only direct practice. Furthermore, these studies found no significant effect of distributed or variable practice, suggesting that the strengths of dyad training are not due to these mechanisms. In sum, the results demonstrated that when completing only half of the amount of practice as an individual, observational learning in addition to direct practice is necessary for dyad trainees to achieve equitable performance to those trained individually. Shebilske et al. (1998) cautioned that other tasks using the AIM dyad protocol would likely need "to provide the necessary information for social learning theory's critical processes of motivation, attention, encoding, and production" (p. 538).

Shea et al. (1999) also used dyad training on a balancing device, called a stabilometer, which required trainees to balance themselves on an unstable board. Practice was manipulated by alternating partners after each trial (dyad-alternate) or requiring one partner to complete half of the trials first while the other observed and then switching roles (dyad-control). The results showed that dyad-alternate participants performed better than individuals and dyad-control participants. These results suggest that the AIM protocol can be used for this type of physical skill if the task can be split into two separate parts in which dyad partners can jointly participate. When the task cannot be split into two equal parts, however, training should alternate between direct experience and observational learning for maximum benefit.

With the exception of the stabilometer study (Shea et al., 1999), the training content used in dyad studies has been limited to a complex and dynamic task (e.g., Space Fortress; Gopher, 1993) for which performance is highly predicated on knowledge, speed, and psychomotor skill (Day et al., 1997; Shebilske et al., 1999). Previous AIM dyad studies also trained subjects through multiple sessions across multiple days, allowing participants to reach a certain degree of automaticity on Space Fortress. Toward the end of training, as would be predicted by theories of skill acquisition (Ackerman, 1988), performance was significantly correlated with psychomotor ability (Shebilske et al., 1999). Although there was no difference in performance between individual and dyad trainees in previous research using this complex and dynamic task (Shebilske et al., 1992), it is unclear if these results will generalize to all types of tasks beyond those that are predominantly psychomo-

tor in nature and can be proceduralized. We would expect, for example, that the interactive component of dyad training may detract essential attentional resources from learning and performance, especially when the interaction is not functional. This is likely to be more problematic when the training is on a task that is highly predicated on attentional resources relative to performance on a task that is somewhat proceduralized. It remains to be seen if supporting the underlying processes of observational learning, as predicted by Shebilske et al. (1998), will still lead to effective dyad training when the task has declarative knowledge components that have such attentional demands. Our studies attempt to expand our understanding of dyad training by empirically testing Shebilske and colleague's (1998) predictions on a new task that is predominantly based on declarative knowledge.

Additionally, previous studies did not report measures of the quality of the interaction between the dyad partners. It is likely that not all partnerships are created equal, but there is little research investigating what makes an adult learning partnership more or less successful during skill acquisition. Although other researchers have found that collaborative partners that explain processes and discuss decision making steps generally fare better than those who do not (Dillenbourg et al., 1996), this research has not been done in the context of skill acquisition or when comparing dyad training to individual training. To gain insight into the behaviors partners engage in to aid or detract from learning, we assessed the degree to which the partners prompted each other's metacognitive activity.

Study 1

We investigated the effects of training individually versus training with a partner while learning a task that had a large declarative knowledge component. To expand to a broader organizational audience, the training material in our current studies was chosen to reflect content commonly trained in organizations (Goldstein & Ford, 2002), but did not require fast reaction times or finely tuned motor skills. Specifically, we trained participants to use Microsoft Access, a database software program from the Microsoft Office Suite.

General cognitive ability is an important predictor in learning Microsoft Access (Carter & Beier, 2010). Although Microsoft Access does require the same level of psychomotor and perceptual speed skills that would be involved in manipulating any other computer software (i.e., operating a mouse and keyboard), it does not require excessive hand-eye coordination, the tracking of targets on the screen or fast response times required by a simulation like Space Fortress (Arthur et al., 1997). In sum, learning Microsoft Access would be similar to learning a word processing software spreadsheet, or any other database software—performance is more heavily predicated on declarative knowledge than it is in tasks like Space Fortress (Mané & Donchin, 1989), which have been used in previous dyad research (Arthur et al., 1997; Day et al., 1997; Shebilske et al., 1998).

In line with Shebilske and colleagues' (1998) warning that the processes of observational learning must be supported to implement successful dyad training, the training program for Access still provides the partners with opportunity to extract, encode, and produce each others' actions in practice tasks that provide feed-

back to the learners. Practice tasks in the training program listed specific goals for each task. The dyad partners used one computer to complete the task: Partners were able to see the goals required by the task, watch their partner's actions on the screen, and attempt to produce the same actions when it was their turn to control the task. Feedback on the practice task was provided by allowing trainees to compare the results of their action with a pictorial display of the correct data retrieval in the practice booklet.

To build a working knowledge of the software, the training program used in this study led trainees through modules, each with distinct learning objectives. The practice tasks required the coordination of a series of information cues, acts, and outcomes and were similar to computer programming tasks, which are considered high in complexity (i.e., programming is considered to be high in coordinative complexity, Wood, 1986). In addition, because trainees are not practicing the same task repeatedly during training attentional demands remain high throughout task execution. Given the cognitive demands of the declarative knowledge phase as described by skill acquisition theory, we believed that interactions with a partner during training would likely detract attentional resources from task execution because these interactions may disrupt the learner's organization of the skill. As a result, we hypothesized that people trained in dyads would not perform as well immediately after training as people trained individually (Hypothesis 1).

We chose to assess performance both immediately and after a 1-week period. Practically, we reasoned that a week reflected a reasonable approximation of a delay from the time an employee is trained on a skill and their having an opportunity to use that skill back at work. From a scientific perspective, the 1-week nonuse interval also allowed us to examine whether retention and transfer differed for people trained individually versus those trained in dyads. Because dyad trainees were hypothesized to learn less during training, we also expected that people trained in dyads would perform worse than people trained individually after a 1-week nonuse interval (Hypothesis 2).

We assessed metacognitive activity to determine its relationship with performance in individual and dyad conditions. As with prior studies (Ford et al., 1998; Schmidt & Ford, 2003), we hypothesized metacognitive activity would be positively related to performance (Hypothesis 3). We believed this relationship would hold for both individual and dyad trainees, as increased monitoring of one's learning should be universally beneficial for later performance. Furthermore, partner-prompted metacognitive activity was measured to capture the quality of the collaboration in dyads. Dyad interactions that facilitate metacognitive processing should also be positively related to performance. We hypothesized that reporting greater partner-prompted metacognition would lead to higher post-training performance as the quality of the collaboration should impact learning (Hypothesis 4).

Cognitive ability is consistently found to be the most reliable predictor of training performance (Ree, Carretta, & Teachout, 1995; Ree & Earles, 1991). Because of its high validity in predicting training performance ($r = .33$, Olea & Ree, 1994), we decided to account for cognitive ability prior to assessing any differences in performance between individual and dyad training participants.

Method

Participants

Sixty undergraduate students were trained on Microsoft Access either in dyads (30 participants in 15 dyads) or individually (30 individual participants) and received course credit for their participation. None of the dyad participants knew their partner prior to training. As a prerequisite for participation, participants were required to have no experience with Microsoft Access. Only participants who attended both immediate and follow-up sessions were included in the analysis, resulting in a final sample size of 52 (28 dyad participants and 24 individual participants).

Materials

Access is Microsoft Office's database software program. The training was created by M. Carter (Carter & Beier, 2010) and modified by the first author for this study. The training was presented through PowerPoint shows with accompanying audio instructions. The training consisted of three instruction modules (lasting approximately 10–15 min each), each followed by two practice tasks. The practice tasks required trainees to program queries that would extract a subset of desired information from a database table. Participants were given a paper handout with a pictorial display of the proper outcome that they could compare with their results to determine if they had created the appropriate query. No step-by-step instructions were given, and the training modules could not be reviewed during practice. However, a minimal reference guide was available in booklet form that covered the topics presented during the modules.

Measures

Background characteristics. Cognitive ability and computer experience were assessed with a computerized questionnaire. To assess cognitive ability, participants reported SAT scores, which are representative of other measures of general mental ability (Frey & Detterman, 2004).

Prior computer experience was measured on a 5-item scale as a control variable. Items asked about amount of computer usage and familiarity with relevant computer applications. A sample item is "How much do you feel you are an expert at using Microsoft Excel?" Participants responded on a 1 (*True beginner*) to 7 (*True Expert*) Likert scale ($\alpha = .80$). All participants were required to have no previous experience with Microsoft Access or other database programs.

Metacognitive activity. Participants reported their metacognitive activity using a scale developed by Schmidt and Ford (2003). Items from the scale included: "If I got confused during this training program, I made sure I sorted it out as quickly as possible before moving on." Each item was rated on a 5-point scale, with 1 indicating "almost never" and 5 indicating "almost always" ($\alpha = .81$).

Partner-prompted metacognitive activity. Subjects in the dyad condition responded to a scale measuring how much their partner prompted their metacognitive activity. The 6-item scale was adapted from the Schmidt and Ford (2003) self-reported metacognition measure and was designed to capture partners'

usefulness as a metacognitive prompt (e.g., "If I got confused during the practice tasks, my partner made sure we sorted it out as quickly as possible before we moved on," $\alpha = .86$). Dyad participants were assured that their ratings would not be seen by their partner.

Performance tests. Learning outcomes were measured using two skill-based performance tests, one delivered immediately after training and one completed after a 1-week nonuse interval. The tests required participants to complete a number of tasks in Access that were similar in format to the training practice tasks. No feedback was provided for test questions. The tests measured skills participants practiced during training and also included adaptive components not directly trained, such as identifying problems in a predesigned query.

Participants were awarded partial credit for answers as points were earned for each step of the task completed correctly. Each test was composed of five different tasks, and tasks ranged from 13 to 41 points in value, with more complex tasks worth more points. The questions on both tests were designed to assess the same underlying concepts, but the immediate and follow-up tests were not identical and not intended to be parallel test forms. The total score for each test was represented as the number of points awarded for accomplishing the objectives divided by the number of points possible, yielding a possible score of up to 100%.

Procedures

The study consisted of two laboratory sessions. In Session 1, participants were randomly assigned to either the individual or dyad training condition. All participants were told they would be trained to use Microsoft Access, they would be tested at the end of training, and they would need to return to the lab 1 week later to complete a follow-up test. After completing the background measures, participants were instructed to listen attentively to the presentations and reminded that they would be tested upon the completion of the training. A booklet of practice tasks and a reference manual created by the experimenter were present on the computer desk. Participants completed all sections of the training without any outside assistance. If they solicited assistance from the experimenter, they were reminded that they could use the reference manual.

In the dyad condition, the instructions clearly stated that the participants would be tested individually, not as a pair, and partners were instructed not to talk to each other during the training presentations. Instructions at the start of each practice task stated which partner would be in control of the computer for each task, and also indicated that they were welcome to communicate with their partner to complete the tasks. Each partner controlled the mouse and keyboard for one of the two practice tasks per session, thereby allowing each participant to get direct and observational learning experience practicing the concepts presented in the module. The partner in control of the first task for the section was counterbalanced across modules.

After the conclusion of training, all tests and measures were completed individually. All participants reported their metacognitive activity, and dyad participants additionally reported their partner's metacognitive prompting. Each participant then took the immediate performance test. Session 1 took 2.5 hrs to complete. At the end of Session 1, all participants were instructed not to use or

discuss Access prior to the next session. One week later, participants returned to the lab for Session 2. No review or additional training was given before the follow-up test. Participants completed the follow-up test and were debriefed and thanked for their participation. Participants took up to 1 hr to complete Session 2. The study procedure is graphically shown in Figure 1.

Results

Means for all variables are listed by condition in Table 1. The scores on the immediate and follow-up performance tests were highly correlated with one another ($r = .59, p < .001$).

Analysis Strategy

Prior dyad training studies used mixed factorial analysis of variance (ANOVA) to analyze performance. However, this violates the assumption of independent samples. If the persons' scores within a dyad are nonindependent, the interpretation of the significance tests for a mixed factorial ANOVA may be overly liberal or overly conservative (see Kenny, Kashy, & Cook, 2008 for a discussion of analyzing dyad partner data). Although prior studies have treated each person's performance as an independent observation and did not report whether partners' scores were correlated with one another, we were concerned that participants in a dyad may be nonindependent as they shared the training experience. Multilevel modeling is a statistical approach appropriate for analyzing participants within groups. This approach can estimate the effects of individual level variables (Level 1) and group level variables (Level 2) on the dependent variable of interest. Using hierarchical linear modeling (HLM; Bryk & Raudenbush, 1992), we were able to control the variance associated with group membership (i.e., the impact of being partnered with a particular person) while still analyzing performance scores at the individual level.

The analysis in HLM was setup such that each dyad pair composed one group and each individual composed a group of his or her own. Condition served as a group-level variable (Level 2), and all other variables were modeled at the individual level (Level 1). Within this framework, we were able to investigate individual-level main effects as well as group-level main effects: 1) individual-level cognitive ability and computer experience effects on individual-level performance, and 2) group-level condition (Individual vs. Dyad) effect on individual-level performance.

Main Effect of Condition

To test the hypothesis that individuals would perform superiorly to dyads after controlling for the effect of cognitive ability and computer experience, we tested the following model:

$$\text{Level 1: } Y = \beta_0 + \beta_1 * (\text{Cognitive Ability}) \\ + \beta_2 * (\text{Computer Experience}) + R$$

$$\text{Level 2: } \beta_0 = \gamma_{00} + \gamma_{01} * (\text{Condition}) + U_0$$

$$\beta_1 = \gamma_{10}$$

$$\beta_2 = \gamma_{20}$$

The coefficients in the model are analogous to unstandardized regression weights. Because our main variable of interest was a group-level variable (Condition), we centered cognitive ability and computer experience at the grand mean (see Enders & Tofighi, 2007). As expected, cognitive ability was positively related to immediate test performance (see Table 2). Computer experience was not significantly related to performance ($p = .06$). Prior studies had not found differences between dyad and individual trainees at the end of training, but we had anticipated differences in conditions due to dyad interactions interfering with the current

Prior to Training (Session 1)	Training (Session 1)	Post-Training (Sessions 1 and 2)
Demographics Computer Experience Cognitive Ability (SAT)	Conditions: 1) Individual – completed all tasks alone 2) Dyad – swapped control between tasks Training Module 1 <ul style="list-style-type: none"> Practice Task 1 – Partner A Practice Task 2 – Partner B Training Module 2 <ul style="list-style-type: none"> Practice Task 3 – Partner B Practice Task 4 – Partner A Training Module 3 <ul style="list-style-type: none"> Practice Task 5 – Partner A Practice Task 6 – Partner B 	Metacognitive activity Partner-prompted metacognitive activity (Dyads only) Immediate test -----1 week later----- Follow-up test

Figure 1. Visual depiction of Study 1 procedures.

Table 1
Study 1: Means by Condition

Variable	Individual (<i>N</i> = 24)		Dyad (<i>N</i> = 28)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Cognitive ability (SAT)	1382.08	169.98	1445.36	78.15
Computer experience	22.50	5.06	21.50	4.80
Metacognition	2.99	.71	2.96	.61
Partner-prompted metacognition			3.34	.89
Immediate test	68.73	12.43	65.00	15.94
Follow-up test	75.99	14.66	69.20	15.08

Note. Cognitive ability was measured as the sum of the math and verbal sections (400–1600). Computer experience was measured on a scale of 5 to 35. Metacognition measures ranged from 1 to 5. Test scores represent percentages.

task's continuous attentional demands (Hypothesis 1). This hypothesis was not supported for immediate test performance. Although individuals trended toward higher performance than dyads, this difference was not significant.

Cognitive ability was also positively related to performance on the follow-up test (see Table 2). We hypothesized that dyad trainees' performance would be inferior to individual trainees' performance after one week (Hypothesis 2). As predicted, there was a main effect of condition on the follow-up test ($\gamma_{01} = -9.07$, $p < .01$). In sum, these results indicate that individual training was not superior for immediate performance, but was superior for retention 1 week following training.

Metacognitive Activity

We believed that metacognitive activity would be positively related to performance for both individual and dyad trainees (Hypothesis 3), but this hypothesis was not supported. Self-reported metacognitive activity was surprisingly unrelated to immediate ($r = -.17$, $p > .05$) and follow-up performance ($r = -.18$, $p > .05$).

Regarding partner-prompted metacognitive activity, we hypothesized that reporting higher levels of prompting would lead to higher performance, as dyad interactions that encouraged meta-

cognitive processing should bolster learning (Hypothesis 4). We found surprising that after accounting for cognitive ability, computer experience, and immediate test performance, metacognitive prompting from a partner was negatively related to follow-up test performance (see Table 3; $\beta_4 = -4.29$, $p < .05$). Hypotheses 3 and 4 were not supported, as metacognitive activity was unrelated to a learner's performance and negatively related to follow-up performance when the metacognitive activity was prompted by one's partner.

Discussion of Study 1

This study expanded previous work in dyad training by using a task where performance was more highly predicated on declarative knowledge relative to the tasks that have been used previously in dyad research (e.g., tasks that have a high psychomotor component; Day et al., 1997). We also expanded prior research by assessing performance both immediately and 1 week following training. In contrast to other research on dyad training, we found that training in dyads was not as effective as training individually after a 1-week nonuse interval. Consistent with the theoretical framework of skill acquisition, these results suggest that when learning cannot be proceduralized and remains in the declarative knowledge phase, dyad interactions can detract from learning. We believed that partner interactions may be beneficial if they successfully prompted metacognitive processes, but the results revealed a negative relationship between reporting partner-prompted metacognition and later tests of performance. While contrary to our predictions, this result is consistent with collaborative inhibition findings that show teammates' contributions to the task can interfere with a person's retrieval of information from memory (Basden et al., 1997). Although observational learning in dyads may facilitate knowledge acquisition as others have found (Shebilske et al., 1998, 1999), perhaps the interactions between dyad partners (even when on-task and prompting metacognitive activity) are generally negative when the task to be learned is still in the declarative knowledge phase: Specifically, it seems that these interactions detract attentional resources from the task to be learned or disrupt the learner's already-engaged metacognitive processes in executing the skill. In Study 1, however, we did not test different types of dyad collaboration, so we cannot conclude about the generality of the negative effect of partner interactions.

Table 2
Study 1: Predicting Performance Using Hierarchical Linear Modeling (HLM)

	Coefficients	<i>SE</i>	d.f.
Immediate test			
Cognitive ability	.03*	.01	48
Computer experience	.63	.32	48
Condition	-4.86	2.98	36
Follow-up test			
Cognitive ability	.03*	.02	48
Computer experience	.41	.37	48
Condition	-9.07**	3.27	36

Note. Coefficients are analogous to unstandardized regression weights.
* $p < .05$. ** $p < .01$.

Table 3
Study 1: Predicting Follow-Up Test Performance With Partner-Prompted Metacognition Using Hierarchical Linear Modeling (HLM)

	Coefficients	<i>SE</i>	d.f.
Follow-up test			
Cognitive ability	.03	.04	23
Computer experience	.18	.34	23
Immediate test	.45**	.13	23
Partner-prompting	-4.29*	1.97	23

Note. Coefficients are analogous to unstandardized regression weights.
* $p < .05$. ** $p < .01$.

Type of Dyad Collaboration

Another reason for the difference in our results versus those of previous research may be function of the type of dyad collaboration. Because the method used in this study did not require partners to be actively interlocked in precisely the same manner as previous dyad studies (i.e., the AIM protocol; Shebilske et al., 1992), dyad trainees may not have invested effort into observational learning when it was their partner's turn to complete the practice task. Instead, dyad trainees may have reduced their effort when it was their partner's turn to engage in the task, which led to poor test performance. Social loafing is defined as a "reduction in motivation and effort when individuals work collectively compared with when they work individually" (Karau & Williams, 1993, p. 681). Previous social loafing studies have found that people are likely to put forth less effort toward a task when they are part of a group than when they are expected to complete the task individually (Karau & Williams, 1993; Latané, Williams, & Harkins, 1979). While this effect increases with group size, even dyads exhibit a reduction of effort of up to 66% compared to that which they would have put forth individually (Latané et al., 1979). Because dyad partners swapped control of the task between practice trials, partners who were engaged in observational learning may have been less likely to attend to the practice tasks because they perceived their individual contribution to the task as ambiguous or redundant when their partner was in control of the computer. The type of collaboration that allows dyad training to be effective may extend beyond observational learning and direct practice and require specific constraints to reduce social loafing.

Several constraining factors have been identified to minimize social loafing, two of which are inherent in the original AIM dyad protocol (Shebilske et al., 1992). First, making individual contributions toward the task identifiable reduces social loafing, presumably because individuals loaf because they are able to hide within the group (Williams, Nida, Baca, & Latané, 1989). Study 1 informed participants that they would be tested individually to emphasize individual accountability for learning, but it is possible that this warning was not strong enough to minimize loafing during task practice. The second constraining factor inherent in the AIM protocol, but not included in Study 1 was the interdependence of group tasks. This reduces social loafing because individuals who are part of a group are not able to complete tasks without the efforts of all group members (Karau & Williams, 1993; Karau & Williams, 1995; Weldon & Mustari, 1988). Study 2 will introduce social loafing constraints in a dyad condition to determine the importance of these factors for dyads to perform as well as individuals.

Metacognitive Activity

In Study 1, self-reported metacognitive activity was not predictive of performance, and partner-prompted metacognitive activity was negatively related to later performance. The subscale for partner-prompted metacognitive activity was intended to measure the quality of the interaction between dyads; for example, the partner's helpfulness in thinking about one's cognitive processes. It may be, however, that the partner-prompted metacognitive scale measured the degree to which the participant was relying on the partner for help to get through the training (i.e., the degree to

which the participant was substituting the partner's metacognitive prompts for their own engagement in metacognition). Consistent with this concern, Webb (1991) found that learners who provide explanations to a partner tend to benefit from the interaction more than the partner receiving the explanation. Another possibility for these findings is that metacognitive prompting received while performing a task may be perceived as evaluative and bothersome rather than helpful (e.g., a backseat driver). Additionally, prompting received by listening to one's partner reason through difficulties while observing them may not be effective for learning if the observer is putting little effort into the task. Study 2 further investigated the importance of partner-prompted metacognitive activity in a dyad condition that required persistent attention of both trainees.

Study 2

The purpose of Study 2 was to further investigate the effectiveness of dyad training. The results of Study 1 did not align with those found in previous dyad research (Shea et al., 1999; Shebilske et al., 1992, 1998), and we believed that there were at least two reasons for this. The first was the type of task trained (one more focused on declarative knowledge, others more procedural). The second was the type of interaction required of the dyad partners (i.e., the interaction did not include the social loafing constraints inherent in the AIM protocol). To examine the effect of a dyad condition that directly mimics the AIM protocol that had been used in previous studies (Arthur et al., 1997; Shebilske et al., 1992), Study 2 introduced a new dyad condition that made individual contributions explicit and required interdependence to complete training tasks. In this new condition, each trainee controlled either the mouse or the keyboard for each task while their partner controlled the other input device. This setup was more closely aligned with previous dyad studies that also divided the task responsibilities by using two separate input devices to accomplish the task (Shebilske et al., 1992). In Access, mouse movement is required to begin a query and enter more macrolevel programming commands. Keyboard typing is required to specify criteria (names or dates) and implement functions (and/or, >, <). Participant input to the task (or lack thereof) was thus apparent during practice. Trainees in this new condition were called Interdependent Dyads (I-Dyads), as opposed to Switching Dyads (S-Dyads) who alternated control of the whole computer between tasks as described in Study 1.

If the type of dyad collaboration in training is crucial to performing as well as individual trainees, then I-Dyad trainees and individual trainees should not differ on tests of performance. If the detrimental effect of training in dyads in Study 1, however, was due to the task related differences as predicted by skill acquisition theory, then altering the type of dyad collaboration should not improve performance to the equivalent of individually trained persons. Because individuals performed better than dyads on both tests but the difference on the immediate test was not significant, we increased the sample sizes for Study 2 and believed individual training would exhibit an advantage on both performance tests. We hypothesized that individually trained participants would still outscore S-Dyads and I-Dyads due to the attentional demands required by the task (Hypothesis 1). We also hypothesized that highlighting task interdependency and individual contribution in

the I-Dyad condition would allow trainees to outperform those in the S-Dyad condition (Hypothesis 2).

By forcing interdependency of dyads in the practice tasks, the I-Dyad condition would require attention and focus of both dyad partners. Metacognitive activity prompted by one's partner in an I-Dyad, then, may reflect the partner's encouragement of self-regulatory monitoring rather than serving as a measure of reliance on the partner as in Study 1. Additionally, by requiring both partners to attend to the task, the I-Dyad manipulation should ensure dyad interactions during training are task-related. We also reasoned that because I-Dyads were working together on the tasks, partner-prompting would be less likely to feel evaluative compared to partner-prompting in S-Dyads. Study 2 investigated the potential difference in quality of the dyad interaction by comparing partner-prompted metacognition in S-Dyads and I-Dyads. If the constraints in I-Dyads alter the quality of the collaboration between dyads, there may be a positive relationship between reported partner-prompted metacognitive activity and performance. We hypothesized an interaction between partner-prompted metacognitive activity and dyad type, such that partner-prompting would again be negatively related to later performance for S-Dyads but positively related to later performance for I-Dyads (Hypothesis 3).

In Study 2, we investigated the type of collaboration (S-Dyads vs. I-Dyads) and examined the quality of the collaboration (partner-prompted metacognition) to determine if our findings from Study 1 differed from prior studies due to a lack of interdependency between dyads in training. We also increased the sample sizes in each condition for Study 2 to increase power. The effect size of the performance difference (adjusted for cognitive ability and computer experience) in Study 1 was .54, defined as a medium sized effect by Cohen (1988). To have adequate power to detect this effect, at least 50 participants were needed in each group (150 total, which would provide power of at least .80, $\alpha = .05$).

Method

Participants

Participants were 153 undergraduate students (69 male, 84 female) who were given a choice between course credit and \$30 for their participation. In total, there were 51 Individual trainees, 52 S-Dyad trainees (26 pairs), and 50 I-Dyad trainees (25 pairs). One trainee in the individual condition did not report an SAT score, and

two S-Dyad trainees did not return for the second session. These participants were excluded from analyses, resulting in 50 participants in each condition with 25 pairs in each dyad condition.

Measures

The same measures were used as in Study 1 (ability, computer experience, metacognitive activity, and immediate and follow-up performance tests). The estimated reliability of each measure in this study was: computer experience ($\alpha = .72$), self-reported metacognitive activity ($\alpha = .83$), and partner-prompted metacognitive activity ($\alpha = .77$).

Procedures

Participants were randomly assigned to one of three conditions: individual, S-Dyad, or I-Dyad. After completing background measures, participants were given instructions according to their condition. Individuals and S-Dyads completed training in the same manner as described in Study 1. I-Dyads were informed that they would need to work together to complete the training tasks, as each partner would be required to control either the mouse or the keyboard for each practice task. All participants were told they would complete a test individually at the end of the training. At the conclusion of each training module, instructions indicated which partner would control the mouse and which partner would control the keyboard during the next practice task. Instructions stated that partners were welcome to communicate with each other in order to complete the practice tasks. After the task was completed, I-Dyad trainees were instructed to switch control of the mouse and keyboard, such that each partner received experience using the keyboard and the mouse for the concepts covered in the training module. Participants completed the same metacognitive activity measures and immediate and follow-up tests after training as detailed in Study 1. All participants were instructed not to use or discuss Access with others until they completed the study.

Results

Tests were scored in the same manner as described in Study 1. Means by condition for all variables are in Table 4. The scores on the immediate and follow-up performance tests were highly correlated with one another ($r = .59, p < .001$). In order to account

Table 4
Study 2: Means by Condition

Variable	Individual (<i>N</i> = 50)		S-Dyad (<i>N</i> = 50)		I-Dyad (<i>N</i> = 50)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Cognitive ability (SAT)	1460.10	103.07	1414.61	110.66	1457.70	102.27
Computer experience	21.53	4.06	21.90	3.90	21.52	4.00
Metacognition	2.99	.74	2.98	.64	3.06	.63
Partner-prompted metacognition			3.20	.80	3.20	.81
Immediate test	78.03	14.75	64.43	17.18	68.69	15.38
Follow-up test	82.76	10.19	73.24	14.90	76.26	12.79

Note. Cognitive ability was measured as the sum of the math and verbal sections (400–1600). Computer experience was measured on a scale of 5 to 35. Metacognition measures ranged from 1 to 5. Test scores represent percentages.

for the effect of being in a particular group (individual, S-Dyad, I-Dyad), we analyzed the data using the same HLM (Bryk & Raudenbush, 1992) framework described in Study 1. Each dyad pair composed one group, while each individual composed a group of their own. Condition served as a group level (Level 2) variable, while all other variables had been measured at the individual level (Level 1). To account for multiple conditions in regression, we used Individual as the reference condition and coded one variable to represent S-Dyads and a second variable to represent I-Dyads.

Main Effect of Condition

To test the hypothesis that individuals would perform superiorly to dyads after controlling for the effect of cognitive ability and computer experience, we tested the following model (with cognitive ability and computer experience grand-mean centered to produce a meaningful zero-point):

$$\begin{aligned}\text{Level 1: } Y &= \beta_0 + \beta_1 * (\text{Cognitive Ability}) \\ &\quad + \beta_2 * (\text{Computer Experience}) + R \\ \text{Level 2: } \beta_0 &= \gamma_{00} + \gamma_{01} * (\text{S-Dyad}) \\ &\quad + \gamma_{02} * (\text{I-Dyad}) + U_0 \\ \beta_1 &= \gamma_{10} \\ \beta_2 &= \gamma_{20}\end{aligned}$$

Predicting immediate test performance, there was an individual-level effect of cognitive ability (see Table 5). Additionally, there were main effects of condition as predicted in Hypothesis 1, indicating that Individual trainee performance was superior to both S-Dyad and I-Dyad trainees ($p < .001$) in both immediate and follow-up test performance. To address the a priori hypothesis that I-Dyads should outperform S-Dyads due to constraints on social loafing (Hypothesis 2), analyses were rerun with I-Dyads as the reference group to determine if any differences existed between these two conditions. Results demonstrated that there were no reliable differences between dyad groups for immediate ($\gamma_{02} = -1.36, p = .62$) or follow-up performance ($\gamma_{02} = .16, p = .95$).

Table 5
Study 2: Predicting Performance Using Hierarchical Linear Modeling (HLM)

	Coefficients	SE	d.f.
Immediate test			
Cognitive ability	.05***	.01	143
Computer experience	.02	.32	143
S-Dyad	-11.25***	2.96	96
I-Dyad	-9.29***	2.46	96
Follow-up test			
Cognitive ability	.01**	.01	143
Computer experience	.27	.23	143
S-Dyad	-7.93**	2.44	96
I-Dyad	-6.40**	2.27	96

Note. Coefficients are analogous to unstandardized regression weights.
** $p < .01$. *** $p < .001$.

Thus, Hypothesis 2 was not supported. The means and standard errors for performance by group are shown in Figure 2.

Metacognitive Activity

Self-reported metacognitive activity was unrelated to performance ($r_{\text{immediate}} = -.07, r_{\text{follow-up}} = .03, p's > .05$). In line with our expectations, reporting metacognitive prompting from one's partner was related differentially with performance by dyadic condition. For I-Dyads, this prompting had no relationship with immediate test performance ($r = .00$) and trended toward positive for later test performance ($r = .24, p = .10$). In contrast, S-Dyads were negatively affected by their partner's prompting on both immediate ($r = -.28, p < .05$) and follow-up performance ($r = -.43, p < .01$). We tested the cross-level interaction of dyad condition influencing the relationship between metacognitive prompting and follow-up test performance (Hypothesis 3), and controlled for cognitive ability and computer experience (see Table 6). The main effect of condition was not significant ($p > .05$) while the main effect of partner prompting was significant ($\beta_3 = 4.11, p < .05$) as was the interaction ($\gamma_{21} = -10.93, p < .001$). Thus, Hypothesis 3 was supported. The more partner-prompting an S-Dyad trainee reported, the worse the trainee did on the follow-up test: In contrast, more partner-prompting in the I-Dyad condition led to better follow-up performance. This interaction was graphed by calculating follow-up test performance for partner-prompted metacognition at one standard deviation above and below the mean (see Figure 3). This suggests that the quality of the collaboration in the two dyad conditions may vary by the way partners interact and support one another's learning. However, this effect did not lead to higher performance, as dyadic conditions did not differ reliably on performance.

Discussion of Study 2

In this study, I-Dyads were given specific parameters designed to constrain social loafing in order to achieve performance similar to individually trained participants after training. These parameters, however, did not significantly bolster performance, and the I-Dyads performed similarly to the S-Dyads. Although the relationships between metacognitive prompting and later performance suggest that I-Dyad partners may support each other's learning differently from S-Dyads, this difference did not translate to increased performance. The differences between dyads and individuals were significant at both performance time points revealing a strong main effect of condition across performance points; individuals simply outperformed both S-Dyads and I-Dyads.

The I-Dyad condition was designed to control somewhat for social loafing and the lack of a reliable difference between I-Dyads and S-Dyads suggests that social loafing is not the culprit for lowered performance by dyads after training. Our results differ from previous dyad studies (Day et al., 1997; Shebilske et al., 1999), and we believe these findings reflect important differences in the type of tasks used to study dyad training. The benefits of dyad training were previously tested with a complex cognitive task that has significant psychomotor elements. In these studies, that largely used Space Fortress, trainees seemed to have proceduralized several components of training and performance was thus predicted by psychomotor ability (Day et al., 1997; Shebilske et

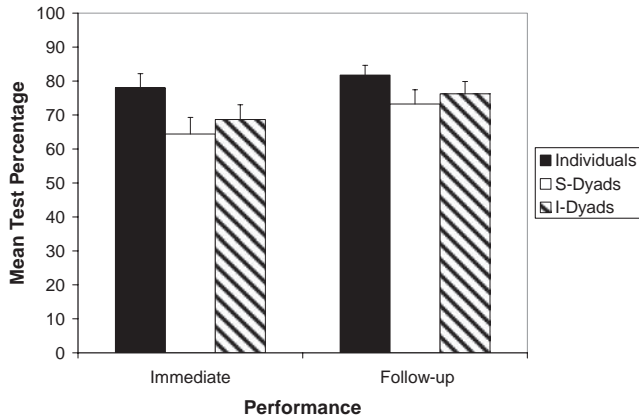


Figure 2. Study 2: Performance by condition after training (error bars represent 2 SE).

al., 1999). With these components being performed fluidly and with relatively little concentration, trainees were then able to use their cognitive resources to focus on observation of their partners' actions and strategies. In contrast, the Access training required a heavy load of declarative knowledge, and each new practice situation incorporated new learning objectives. As such, learners could not truly move into the procedural phase of skill acquisition and attentional demands remained high. As a result, dyad trainees needed to think about each component in a stepwise fashion, leading to possible confusion while trying to observe one's partner at the same time. Additionally, dyad interactions during this phase of skill acquisition, even if germane to the content, may have overtaxed a trainee's attentional resources or disrupted online metacognition already at work, making it difficult for them to perform as well as individuals after training.

General Discussion

We examined the effectiveness of dyad training for tasks that focus more on declarative knowledge learning that may not be proceduralized. The current findings are discrepant with previous dyad training studies: Individuals outperformed dyads on both immediate and delayed performance tests. The results caution the use of dyad training for tasks heavy on declarative knowledge with the expectation that dyads will perform as well following the training as individually trained persons. Prior researchers predicted

Table 6

Study 2: Metacognitive Prompting From a Partner and Follow-Up Performance Using Hierarchical Linear Modeling (HLM)

	Coefficients	SE	d.f.
Follow-up test			
Cognitive ability	.02	.01	93
Computer experience	.42	.29	93
Partner prompting	4.11*	1.86	93
S-Dyad	-1.91	2.52	48
S-Dyad \times partner prompting	-10.93***	2.69	93

Note. Coefficients are analogous to unstandardized regression weights. * $p < .05$. *** $p < .001$.

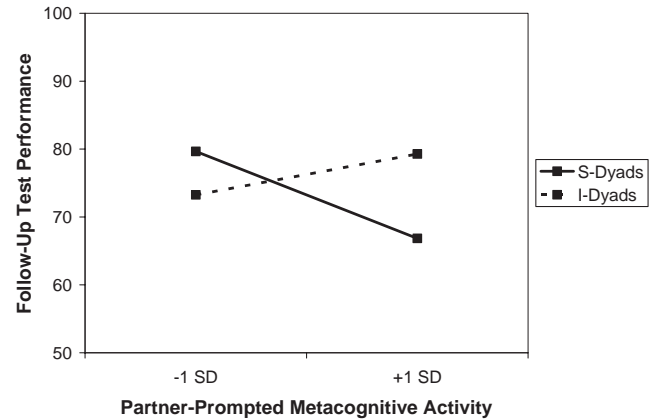


Figure 3. Study 2: Interaction of partner prompting and dyad condition.

that there would likely be boundary conditions on the effectiveness of dyad training (Shebilske et al., 1998), and these studies serve to advance our understanding of those boundaries.

Study 2 investigated the importance of the type of dyad collaboration used during training, comparing an interdependent dyad condition with social loafing constraints to an alternating dyad condition to determine if such constraints would allow dyad trainees to perform as well as individuals on the task. Results suggest that weakened task interdependence and minimal individual accountability in training were not the causes of decreased performance for dyads in Study 1, as both I-Dyads and S-Dyads in Study 2 failed to achieve performance of individually trained people. The performance of I-Dyads was not significantly better than S-Dyads and the self-reported quality of the interactions was similar for both dyad types. This suggests that the quality of the interaction between dyad partners and social loafing played minor roles in comparing dyad training to individual training.

Nonetheless, the quality of the collaboration for I-Dyads and S-Dyads did differ in their relationship to performance: Partner-prompted metacognition in I-Dyads supported learning in a way that was more beneficial for long-term performance. Because S-Dyads were not actively interlocked in tasks, it may be that partners had distinctly different metacognitive paths; these differences could be in pace (how quickly one partner moved from concept to concept compared to the other), sequence (how they prioritized adding different programming elements), or other metacognitive process features (how frequently they ran code to check their progress). Conversely, in I-Dyads, where both learners were interlocked and had to coordinate actions for each task, trainees may have been better able to use their partner's prompting as a seamless extension of their own metacognition. The pace, sequence, and process features of each interaction had to be at least somewhat negotiated between I-Dyad partners in order to proceed in the practice tasks. This explanation is consistent with research on collaborative inhibition, which argues that working with another person becomes detrimental if the collaboration disrupts one's own structure of information retrieval (Basden et al., 1997). Perhaps S-Dyads are more susceptible to disruption because each person is engaged in their own metacognitive processes, whereas I-Dyads are sharing a metacognitive approach to the problem. One cannot overlook, however, that the I-Dyad and S-Dyad conditions

did differ in multiple ways that may have affected the relationship between partner-prompting and performance, including the training instructions that informed I-Dyads they needed to work together to complete the practice tasks. Future studies should further investigate the process differences between these two forms of collaboration.

We believe these findings highlight the importance of considering the task when determining if dyad training is appropriate. The difference in individual and dyadic performance in the current studies suggests that dyad training is not as effective for tasks that are difficult to proceduralize and require constant attention. Training programs that focus more heavily on skills that remain in the declarative knowledge phase of skill acquisition must consider the possible consequences of training in dyads.

In addition to the difference in task types between studies, it is possible that observational learning in the current studies was not as effective of a learning mechanism as it was in prior dyad studies. We earlier described two processes that are absent in individual learning but present in collaborative training: observational learning (modeling) and interaction. While we attempted to measure and manipulate partner interaction in our dyads, we did not investigate the success of observational learning. Bandura's social learning theory (1986) requires that observer be aware of the consequences of the modeler's behavior for observational learning to take place. The type of feedback provided in the current training context may have disadvantaged dyads. In the Space Fortress task, knowledge is demonstrated through action that is observable on the screen: flying the plane in a particular pattern, firing missiles at a particular target, and so on (Mané & Donchin, 1989). Scores are represented in real-time at the bottom of the screen, providing instant feedback. Therefore, observing one's partner can be a very effective medium for learning new patterns of action or strategy as the results are clearly connected to accompanying actions. In Microsoft Access, observers are able to see positive and negative outcomes by comparing resulting datasets in practice tasks with a graphic of the correct dataset, but feedback is provided only after the trainee runs the query. Some trainees checked their progress on a task more frequently than others. As a result, the time between modeler's actions and outcomes was sometimes significantly longer than previous studies and may have impeded observer's ability to connect appropriate actions with resulting outcomes. Information encoded from observation, then, may be more susceptible to improper attribution of actions with outcomes or a general uncertainty in how the outcome was acquired. Dyads may have performed inferiorly to individuals, not because their interactions distracted from the task, but because their observational learning was not robust due to time between the modeler's actions and the feedback. Declarative knowledge tasks require much cognitive processing that is difficult to observe, potentially heightening the need for clear and immediate feedback on the observable actions made by a partner. Shebilske and colleagues (1998) cautioned that observational learning should be robustly integrated into a dyad training paradigm in order to be successful. Future research, therefore, should more fully investigate the role of immediate feedback in supporting observational learning when training dyads in different types of tasks.

One cannot rule out the possibility that there are other relevant differences between the task used in this research (MS Access) and those used in previous studies of dyad training (e.g., Space For-

tress). Task differences exist between the current studies and other recent studies that investigate collaborative problem-solving on tasks that overload an individual's working memory (Kirschner, Paas, & Kirschner, 2010). These different types of tasks may lead to different conclusions about the effectiveness of training with others. In order to better understand the contingencies required for dyad training to be effective, a wide range of task types should be investigated across acquisition stages. Perhaps skills with a more salient social aspect (such as public speaking or negotiating) are appropriate tasks for dyad training because of their social nature, regardless of the amount of declarative content learning required (see Crook & Beier, 2008; Kraiger, 2008).

Contributions of the Current Research

These studies advance the literature surrounding dyad training in a number of ways. First, we examine different types of the dyad interaction by comparing individuals to both S-Dyads and I-Dyads. Additionally, we examined how interactions between dyad partners can contribute or detract from training success. Most team and dyad training studies do not examine the quality of the interaction, and we hope the findings from the current research encourage others to develop and include such measures. Finally, these studies extend previous work by providing empirical support for the boundary conditions on the use of dyad training. Task features should be considered before choosing to train individually or in dyads. Based on the studies' findings, we believe that training individually is likely to be more effective than training in dyads when the task has a large declarative knowledge component. Additional work in identifying task features and other boundary conditions for dyad training is greatly needed.

Limitations

While we have argued that our findings are consistent with theories of skill acquisition and resource allocation, we must caution that the underlying ability components of the Access task used in this study have not been fully explored and quantified. Given the descriptions of Space Fortress (Mané & Donchin, 1989), and its ability correlates (i.e., Ackerman, 1988), it appears to be more consistently mapped than Microsoft Access and thus many components are able to be proceduralized. At this time, we do not know the degree to which one could proceduralize various components of Access programming. Therefore, our assertions about the differences between these two tasks are more regarding the relative importance of abilities and available resources required for performance than absolute levels.

In addition, we may not understand all of the important elements of a functional interaction between dyad partners. We focused on the quality of the interactions between dyad partners as measured by the partner-prompted metacognitive measure, but other ways of measuring this interaction may also prove useful. As pointed out by one reviewer, the current interaction measure addressed the degree to which on-task interactions occurred, but did not distinguish between partner prompting that was disruptive versus informative to the learner. Future research in dyad training should consider using this and other measures of dyad interaction to identify the processes relevant to dyad training success.

Another potential limitation of the current studies is that the participants were very high in cognitive ability compared to the general population. It is possible that dyad training may provide useful support for lower or average ability levels when compared to individual counterparts. Day and colleagues (2005) compared training in high ability teams, low ability teams, and mixed ability (one high and one low partner) teams, with performance assessed individually both during and after training. High-ability people did best on individual measures of performance when they learned with another high-ability team member, while low-ability people did not benefit much from learning with a high-ability team member. These teams were not compared to individually trained counterparts, but the results suggest that the current studies' teams of all high-ability learners should have provided the optimal environment for learning. Still, a wider range of ability levels could be considered in future studies of dyadic training, as average or low ability individuals may benefit from training with a partner as opposed to training alone.

Implications

Our findings imply that dyad training is not equivalent to training individually for all types of training content. We have argued that if the learner cannot progress through the stages of skill acquisition that training with a partner will detract from attentional resources needed for learning. The results of the current studies indicate that working with others during this time may impede knowledge compilation rather than facilitate it. Future research is needed to investigate the task parameters that may influence dyad training. To maximize learning in tasks with a heavy declarative knowledge component, individual training appears to be the most effective approach.

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New Editor Appointed for *Sport, Exercise, and Performance Psychology*, 2012–2016

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