Journal of Applied Research in Memory and Cognition 3 (2014) 252–260

Contents lists available at ScienceDirect

Journal of Applied Research in Memory and Cognition

journal homepage: www.elsevier.com/locate/jarmac

The effects of collaborative practice on statistical problem solving: Benefits and boundaries

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ARTICLE INFO

Article history:
Received 1 February 2014
Received in revised form 30 May 2014
Accepted 22 June 2014
Available online 28 June 2014

Keywords:
Collaboration
Memory
Learning
Statistics
Repeated practice

ABSTRACT

In recent years, understanding the effects of collaboration on learning and memory has emerged as a major topic of investigation. Findings from applied educational research and from basic cognitive research demonstrate a complex view of how collaboration affects learning. The present laboratory study bridged these two domains of research to address the question of how collaborative learning affects statistical problem solving. After viewing a lecture, participants completed two statistics tests. They either completed the tests collaboratively and then individually, or completed both tests individually. Results showed an immediate benefit of collaboration, but this benefit did not persist on a subsequent individual test. Repeated practice by those who worked individually increased performance to the level of those who had previously collaborated. These results were qualified by gender as females showed a consistent benefit from prior collaboration on the post-collaborative test, particularly on conceptual problems. Implications for education are discussed.

1. Introduction

Across all levels of schooling, small group instruction is one of the most popular methods of learning among both teachers and students alike; groups are organized by teachers for activities in class, as well as by students for studying and doing homework outside of class. Small group learning activities can be employed in just about every academic subject, including those that involve problem solving skills, like math and statistics (Garfield, 1993). As the prevalence of group learning methods in the classroom has increased over the past decades, the efficacy of these methods has become a major topic of research for social, applied educational, and more recently, cognitive psychologists who are interested in the role that the social context plays in shaping learning and memory performance. Scientific evidence suggests that working in groups to learn and remember information is associated with a variety of different outcomes, both positive and negative, and we are only beginning to understand the specific mechanisms that lead to these different outcomes. The present study investigates how collaborative practice affects statistical problem solving, and takes a cognitive perspective to examine it. Rather than examining verbatim memory, the present study investigates remembering in the context of problem solving, that is, how people remember what they have learned to solve particular problems. Such remembering is typical of everyday life and is one of the main contexts in which collaborative remembering often occurs.

Given the educational implications of how people learn and remember in groups, it is not surprising that a considerable amount of educational research has been conducted in this area within classrooms at all levels of schooling. With regard to statistics classes, applied educational researchers have studied the effects of implementing various cooperative learning techniques, finding a range of positive outcomes. For example, Keeler and Steinhorst (1995) found that after incorporating in-class collaborative activities into their introduction to statistics course, a higher percentage of students passed the course in comparison to past semesters when collaborative techniques were not used (also see Magel, 1998). They also found that final grade point averages improved (also see Giraud, 1997), as did student satisfaction with the course. Further, several meta-analyses and reviews have been conducted (e.g. Lei, Kuestermeyer, & Westmeyer, 2010; Lou, Abrami, & d'Apollonia, 2001; Roseth, Johnson, & Johnson, 2008; Slavin, 1980; Springer, Stanne, & Donovan, 1999) to summarize the findings from this expansive body of educational research and to determine recommendations and best-practices for teachers interested in employing collaborative techniques in their classrooms. Findings from these and other reviews and meta-analyses usually highlight the positive outcomes of collaboration such as higher levels of achievement, positive attitudes toward group-work and

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http://dx.doi.org/10.1016/j.jarmac.2014.06.005

peers, positive self-esteem, better attitudes toward learning, and increased persistence in courses and programs. Consequently, collaboration is typically seen as a major success story (Johnson & Johnson, 2009) and the trend in schools is to include collaborative tasks in the classroom whenever possible.

Although these social and academic outcomes are very encouraging, it is important to note that outcomes of collaboration are not always positive (Barron, 2000, 2003; Cooper, Cox, Nammouz, Case, & Stevens, 2008; Crook & Beier, 2010; Gillies, 2003; Salomon & Globerson, 1989; Sfard & Kieran, 2001; Webb, 1982, 1993; Webb, Nemer, Chizhik, & Sugrue, 1998). Individual instances of collaboration can vary in effectiveness depending on factors related to the task (e.g. instruction, resources, complexity, goal-orientation, etc.) the learner (e.g. intelligence, learning style, social skills, etc.), and the group (e.g. group composition, size, etc.). Depending on these and other factors, results can be mixed; compared to traditional learning methods (i.e. individual learning), sometimes there are no academic or social benefits of collaboration, and other times collaboration is associated with lower performance (e.g. Crooks, Klein, Savenye, & Leader, 1998; Gadgil & Nokes-Malach, 2012; Leidner & Fuller, 1997; Slavin, 1980, for a review, see Table 3; Tudge, 1989). Furthermore, research in this discipline rarely focuses on the cognitive components of collaboration and the successes or failures for group and individual performance that might be linked to these components.

Similar to the applied education literature, laboratory research on collaborative memory has also demonstrated both positive and negative outcomes of collaboration. Research demonstrating improved memory as a result of collaboration, also known as collaborative facilitation, has found that under certain conditions groups produce more accurate and more complete accounts of their memories than if they worked independently, such as on a recognition task, working with a familiar partner (e.g., couples), experts collaborating together, or when instructed to be as accurate as possible or reach consensus as a group (e.g., Clark, Hori, Putnam, & Martin, 2000; Harris, Keil, Sutton, & Barnier, 2010; Harris, Barnier, & Sutton, 2012; Meade, Nokes, & Morrow, 2009; Yarmey & Morris, 1998). The benefits of collaboration have also been observed following group memory tasks, that is, in post-collaborative individual performance, when participants who previously remembered studied information in collaboration with group members attempt to remember the same information on their own (e.g., Blumen & Rajaram, 2008).

In contrast to these findings, group remembering is also associated with costs. For example, a classic finding in collaborative memory research is that working in groups leads to sub-optimal individual performance during group recall, a phenomenon known as collaborative inhibition (Basden, Basden, Bryner, & Thomas, 1997; Weldon & Bellinger, 1997). So, even though the net result for the group is greater than what any one person can remember, each individual in the group does not perform up to their full potential. This finding is consistently demonstrated across a variety of tasks, situations, and stimuli (for a review, see Rajaram & Pereira-Pasarin, 2010). Finally, the costs of collaboration can also extend to individual memory, as is seen in studies noting the social transmission of errors (e.g., Roediger, Meade, & Bergman, 2001; Thorley & Dewhurst, 2007, 2009), or post-collaborative forgetting (Basden, Basden, & Henry, 2000; Coman, Manier, & Hirst, 2009; Congleton & Rajaram, 2011).

It turns out that whether or not memory is improved by working with others depends on several interacting processes that occur during collaboration (Rajaram & Pereira-Pasarin, 2010), some that enhance probability of correct remembering (i.e. re-exposure, re-learning through retrieval, and error pruning), and others that reduce that probability (i.e. social contagion of errors, blocking, and retrieval disruption). For example, serving to improve subsequent memory, hearing the responses of one's group members allows for an additional study opportunity (i.e., re-exposure). Additionally, the act of retrieving information from one's own memory can improve later recall through a process similar to rehearsal (i.e., re-learning through retrieval). Finally, by providing feedback during collaboration, group members can eliminate the production of errors in subsequent individual recall (i.e. error pruning). However, just as feedback from the group can reduce the spread of errors, group members can also make errors themselves or incorporate others' erroneous memories. If these errors go uncorrected or unchallenged, these same mistakes can persist during individual recall later, a process known as social contagion of errors (Basden et al., 1997; Roediger et al., 2001; Thorley & Dewhurst, 2007, 2009; Weldon & Bellinger, 1997). Blocking or forgetting of information may occur as a result of waiting while others contribute, or as a result of recalling what comes to mind first. After recalling all of the strongly remembered information, the weakly remembered information can no longer be accessed. Finally, since everyone has their own way of organizing and retrieving information, and hearing the information produced by someone else in a different way may disrupt one's own retrieval.

The aforementioned research largely focuses on verbal study materials (e.g., word lists, and narratives). To date, very few studies have focused on the cognitive components of collaborative learning using educationally relevant materials, and none has specifically focused on statistics learning. The statistical problem solving task in the present experiment differs from much of the traditional collaborative memory literature in that it involves both declarative or conceptual components (i.e. knowing theoretical principles and formulas) and procedural or computational components (i.e. knowing how to implement principles and formulas) (Cohen & Squire, 1980; Mestre, Ross, Brookes, Smith, & Nokes, 2009). Our goal was to investigate whether and how collaborative practice would influence statistics learning for the individual learners in this distinctly different context of learning and performance. In approaching this question, we did not intend to compare group recall and group problem solving; rather, we adapted the broad context of the collaborative memory literature and the general experimental paradigm widely used therein, to develop a controlled, laboratory test of statistics learning by individual learners. The collaborative memory literature provided a useful backdrop also because some mechanisms elaborated therein, e.g., re-exposure and relearning, are relevant for exploring possible changes in individual learning as a function of collaborative practice of statistical content in the present study.

In sum, the findings from collaborative memory research and collaborative learning paint a complex and at times conflicting view of how collaboration affects learning. Despite the considerable research on collaboration that has been conducted across various contexts, the specific effects of collaboration on content-based problem solving (e.g. statistics) remain unclear. Many of the findings within the educational literature are encouraging, but without investigating the effects of collaboration at both the group and individual level under controlled conditions, the reasons behind the demonstrated improvements will remain unspecified. That is, within an applied setting, there are often a number of practical constraints that make it difficult for some basic research design elements (e.g. proper control groups, random assignment to conditions, measurement of dependent variables, etc.) to be carried out with the same level of control that is feasible in a laboratory setting. Moreover, given what we know about the common misconceptions students hold regarding statistics topics (Garfield, 1995) and the challenges students experience with learning and applying conceptual information (Confrey, 1990; Mestre et al., 2009) more research is needed to better understand the extent to which students can benefit from collaboration in statistics courses. When considering