Journal of Experimental Psychology: Applied
2011, Vol. 17, No. 4, 371–381

1076-898X/11/$12.00 DOI: 10.1037/a0025131

The Effects of Group Monitoring on Fatigue-Related Einstellung During Mathematical Problem Solving

Daniel Frings
London South Bank University

Fatigue resulting from sleep deficit can lead to decreased performance in a variety of cognitive domains and can result in potentially serious accidents. The present study aimed to test whether fatigue leads to increased Einstellung (low levels of cognitive flexibility) in a series of mathematical problem-solving tasks. Many situations involving fatigue and problem solving also involve people working in teams. However, little research has considered the role of social processes in managing the effects of fatigue. Research into the group monitoring hypothesis suggests that membership in a team can offset the effects of impairing factors such as fatigue upon performance. Thus, the present study also aimed to test whether group membership exacerbates or ameliorates the negative effects of fatigue. During the course of a weekend military training exercise, participants ($N = 171$) attempted to solve a series of problems either alone or in a team, and while either reasonably alert (nonfatigued) or fatigued through sleep deficit. Fatigued problem solvers working alone showed increased Einstellung. In contrast, and in line with the group monitoring hypothesis, teams of fatigued problem solvers did not experience increased Einstellung. The present study also showed that teams with a group member who was relatively less fatigued experienced less Einstellung than other groups. These effects persisted even once participants were cued toward more direct strategies. These findings highlight the risk of Einstellung when fatigued and also the importance of team membership with reference to problem solving in an occupational context.

Keywords: Einstellung, problem solving, group fatigue, sleep

Fatigue can be described as a physiological and/or a mental state that impairs cognitive performance (see Noy et al., 2011; Rabinbach, 1990). Factors contributing to cognitive or general mental fatigue include high mental workload, sustained work effort, circadian time of day effects, and especially sleep deficit and night work (Krueger, 1989). The present study focuses upon cognitive fatigue resulting from sleep deficit (cumulative sleep loss over a number of nights), which has been linked to fatigue sufficient to impair performance (Van Dongen & Maislin, 2003). Such fatigue can lead to lower quality decision making and poor situational awareness, which can lead to serious accidents (see Miller, Matsangas & Shattuck, 2008; Yegneswaran & Shapiro, 2007). For instance, in the case of transportation operators, fatigue was linked with a third of "on passage" incidents involving large shipping in waters in the United Kingdom between 1994 and 2003 (Marine Accident Investigation Board, 2004). Similarly, a significant proportion of poor medical decisions are made by fatigued workers (e.g., Gander, Miller, Webster & Merry, 2008; Landrigan et al., 2004). Although many of these working populations operate in small groups or teams, little research has addressed the *social processes* that may exacerbate or ameliorate the effects of fatigue. Drawing on social psychological theory, the research reported here aims to address this gap by investigating how fatigue affects problem solving, and the role group or team membership plays in these processes.

This article was published Online First August 15, 2011.

This research was supported by ESRC Grant RES-000-22-3460 and complies with BPS and APA ethical guidelines. The author would also like to thank the London University Officer Training Corps for assistance given. This work has been previously presented at the British Psychological Society Social Section Conference, 2010.

Correspondence concerning this article should be addressed to Daniel Frings, Department of Psychology, London South Bank University, London, United Kingdom, SE1 6LN. E-mail: fringsd@lsbu.ac.uk

Fatigue and Problem Solving

To some extent, fatigue can be deleterious to problem solving in many practical situations, such as the two cited previously. For instance, marine navigators must spot traffic patterns and calculate the safest, quickest route to a destination. Similarly, medical staff must coordinate information to link symptoms, causes and treatments. Fatigue has been shown to interfere with the safe execution of such tasks—for instance, fatigue because of shift work has been linked with a 36% increase in medical errors classed as "serious" (see Landrigan et al., 2004; Papp et al., 2004). Existing research has identified a number of possible processes through which fatigue affects performance, such as simple and complex attention, memory, poor risk perception and slower response time (Ferguson, Paech, Dorrian, Roach & Jay, 2011; Kilgore et al., 2008; Lim & Dinges, 2010).

A further possible, but as yet untested, mechanism that may affect fatigued problem solvers' ability is through a reduction in cognitive flexibility (the ability to shift between problem-solving solutions; see Luchins, 1942), reflected by "Einstellung." Einstellung is said to be present when a problem-solving method that was previously optimal and efficient is retained and causes suboptimal, inefficient performance on a new problem (Luchins, 1942; Luchins & Luchins, 1969). Einstellung is characterized by an inability to shift task sets, inflexible thinking, and an overreliance on previously identified solutions, regardless of their appropriateness. It has been shown to affect both novices and expert problem solvers (e.g., Bilalić, McLeod & Gobet, 2008; Luchins, 1942), is linked to attentional biases (Bilalić, McLeod & Gobet, 2010), and is particularly prevalent when problem solvers are under stress or cognitive load (Schultz & Searleman, 1998).

Understanding whether fatigue induces Einstellung is important, because flexible thinking during problem solving is vital in a variety of contexts, and an overreliance on existing assumptions can be hazardous in any situations where problem environments are changeable (Cañas, Quesada, Antolí, & Fajardo, 2003). For instance, Einstellung during medical diagnosis can lead to possible misdiagnosis if linking symptoms to diagnosis becomes "routine." Military decision makers experiencing Einstellung may overlook potential risks and opportunities in changing situations (see Miller et al., 2008).

The presence of Einstellung is typically tested by using task sets that have multiple problems of the same type, which can be solved using the same solution. After a number of problems are presented (sufficient that the standard solution is expected), *critical problems* are presented that can be solved either with the standard solution or one that is more efficient and subjectively obvious. By testing the extent to which problem solvers fail to recognize and use the more efficient solution, the degree to which they experience Einstellung can be assessed.

To our knowledge, no previous research reports have tested the effects of fatigue because of sleep deficit on the prevalence of Einstellung during problem solving. However, *task* fatigue (fatigue because of sustained effort on repetitive tasks rather than sleep deficit) has previously been linked to inability to switch rules when carrying out the Wisconsin Card sorting task (van der Linden, Frese & Meijman, 2003), which is analogous to an Einstellung effect. In addition, factors that may encourage Einstellung effects (lowered vigilance, impaired executive function) are also increased by fatigue (see Lamond & Dawson, 1999; Williamson & Feyer, 2000).

A common way of testing for Einstellung effects is via the "water jar" mathematical problem set outlined by Luchins and Luchins (1969). In this task, participants answer a series of mathematical problems, divided into two sets. The task is to solve each problem in as few steps as possible. The first set can be solved with a single strategy which, once discovered, consistently solves the problem in the fewest steps possible. A second set of problems is then introduced, which can still be solved using the original strategy, but can also be solved by a novel, even more efficient strategy. Because the aim of the task is to solve the problems in the fewest steps, failing to switch strategies reflects Einstellung. The present study compares the performance of problem solvers who are *fatigued* (because of sleep deficit) or *reasonably alert* (without sleep deficit). Given other effects of fatigue, and the evidence that task fatigue can lead to similar effects to Einstellung, it is predicted that problem solvers will experience greater Einstellung when fatigued than when reasonably alert.

Fatigue and Team Membership

Many occupations involve people working in groups (a number of people who may or may not have a history of working together but who share common goals; see Johnson & Johnson, 1987). Often these groups are *teams*. Teams are the focus of the present investigation and are defined as a group of people who share common goals, have a history of working together, and who have knowledge of various members' strengths and weaknesses (see McGrath, 1984). Examples of teams include doctors and emergency workers operating in shift teams, ships crews working in watches, project teams in creative and engineering industries, and many others.

Despite the prevalence of teams in occupational settings (see Swezey & Salas, 1992), research focusing on ways to ameliorate fatigue typically focuses on managing work-rest cycles to minimize sleep deficit and, in the case of military applications, the controlled use of stimulants to offset it (see Biggs et al., 2007; Caldwell, Mallis, Caldwell, Miller & Neri, 2009; Neri et al., 2002). This focus has resulted in the potential role of *team membership* and associated social processes being very nearly ignored. Theoretical and empirical work suggests that group/team membership may affect the level of Einstellung among fatigued workers in a number of ways.

Social Loafing and Conformity

When effort is divided among members, team membership can lead to some individuals exhibiting poor performance, a phenomenon known as *social loafing* (a reduction in task motivation). This can occur because of reduced effort being expended upon a task (Hart, Karua, Stasson & Kerr, 2004; Karau & Williams, 1993) or because resources are expended attending to social processes rather than the task (Gastorf, Suls, & Sanders, 1980; Muller & Butera, 2007; Muller & Fayant, 2010). Because fatigue can also decrease motivation (Mikulincer, Babkoff, Caspy & Sing, 1989), this effect may be particularly pronounced among fatigued teams. Hoeksema-van Orden, Gaillard, and Buunk (1998) observed social loafing in fatigued groups when group members were unaccountable to one another. However, once group members' effort levels were known to one another, the magnitude of this effect decreased. These findings suggest that when team members are unaccountable to one another, loafing can occur.

In addition to social loafing, group/team membership can also lead to conformity. Research into social conformity indicates that group members (especially in cohesive groups) look to one another for guidance when situations are ambiguous (e.g., Marques, Abrams & Serodio, 2001; Sherif, 1936). Cues for ways to behave are guided by the behavior of individual team members, especially when the behaviors are performed in front of other team members (Abrams, Wetherell, Cochrane, Hogg, & Turner, 1990). This may particularly affect a team's ability to avoid Einstellung. If a nonoptimal strategy is adopted by a team, individual conforming team members may be less likely to intervene with a new, potentially improved, strategy.

A final detriment related to team membership is coordination demands and subsequent process loss (see Steiner, 1972). Groups need to spend time and energy coordinating the dissemination of relevant information and ideas that could otherwise be spent on the task (coordination demands). Failure to communicate relevant information effectively or incidents of team members unintentionally blocking or duplicating others' efforts can also lead to poor performance relative to a similar number of people working independently (process loss).

In summary, team membership may decrease performance in Einstellung tasks in a number of ways. Individual team members may loaf and not attend to the task. In addition, group conformity may stifle the generation of new ideas and more efficient solutions. These negative effects of team membership would be indicated by poor performance (e.g., less problems solved, more Einstellung) among teams relative to individuals. While these effects may be present among reasonably alert teams, they are likely to be particularly pronounced among teams that are fatigued. Because fatigued team members may already be experiencing decreased motivation and exhibiting poor performance, they may be more inclined to loaf than reasonably alert team members. Coordination demands may consume a greater proportion of the (smaller) resource pool available to fatigued teams. Finally, it is also possible that this decrease in motivation makes conformity more likely, hampering the creation of efficient solutions, and leading to increased Einstellung. It is reasonable to suppose that this would be especially problematic for fatigued groups where the possibility of team members initially applying nonoptimal solutions may be greater. If it is the case that fatigued teams are particularly susceptible to these effects, it would be expected that fatigued groups should be outperformed not only by reasonably alert individuals and teams, but also by fatigued individuals.

Social Facilitation and Information Pooling

In contrast to the evidence outlined previously, other research points to the beneficial effects of team membership. Being part of a team can lead to an increase in motivation, encouraging individuals to direct more effort at a task. Specifically, research into social facilitation suggests the mere presence of others can lead to improved performance by increasing the "dominant" response; for example, people try harder and more persistently at tasks they are familiar with (Triplett, 1898; Zajonc & Sales, 1966). This effect occurs particularly when group members perceive themselves and their performance as being accountable to other group members (Geen, 1989). In studying team decision making, Baranski, Thompson, Lichacz, and McCann (2007) observed social facilitation among fatigued groups who undertook interdependent tasks (i.e., tasks where group members separately performed a task and all members had to be accurate for the group to succeed). This suggests that social facilitation can occur among fatigued groups. However, this study was limited in its ecological validity, in that communication among group members was limited, and group members attempted to complete separate parts of the same task, rather than working together on a single problem.

As well as trying harder, being in a group brings the potential benefit of several viewpoints. Groups can monitor the quality of information coming from individual group members and weigh its accuracy and importance before reaching a final decision. This reduces error because outlying judgments are given less weight in final decisions than commonly held ones (Frings, Hopthrow, Abrams, Hulbert & Gutierrez, 2008; Harries, Yaniv, & Harvey, 2004; Yaniv, 2004).

A final mechanism by which the potential detriments associated with team membership can be offset is by the presence of a high-performing team member who can act as an effective leader. Team leaders have been shown to be effective at reducing process loss and increasing motivation by guiding group behavior (e.g., Hogg, 2001). Under conditions of fatigue, an effective leader could be someone who is more capable than other team members either through their ability to motivate others, their task-relevant baseline ability levels (e.g., they are affected by fatigue but are better at a given task), or by decreased susceptibility to fatigue (so they are not as impaired). It is also possible that the probability that the group will contain such a team member is higher than the probability that any one individual will be a "good" problem solver. Thus, if groups perform at a level equivalent to their best member's performance, a team of four people should be more likely to reach the ideal solution than a single individual (e.g., Hill, 1982; Laughlin, Hatch, Silver & Boh, 2006). Previous research has demonstrated the importance of such team members on performance while fatigued: For instance, Haslam and Abraham (1987) showed that groups can operate effectively even under high levels of fatigue if effectively led.

If social facilitation, effort pooling, and leadership gains are present during a task, a consistently better performance (e.g., more problems solved, less Einstellung) can be expected from teams relative to individuals, regardless of fatigue levels. An important conceptual note is that existing research into the benefits of team membership does not specify that the effects of team membership should be amplified (or lessened) by the presence or absence of other, possibly impairing, contextual factors such as fatigue. Thus, no clear predictions can be made as to whether groups will experience differing levels of facilitation under conditions of fatigue or while reasonably alert. One model that begins to address this issue is the *group monitoring hypothesis* (Abrams, Hopthrow, Hulbert, & Frings, 2006).

Group Monitoring

The *group monitoring hypothesis* argues that teams may be relatively unaffected by impairing factors, such as fatigue, relative to individuals. It also argues that benefits of team membership may occur particularly in situations where other contextual factors (such as fatigue) which may impair individual performance are present. There are a number of processes that may underlie this protective effect. Individual team members may be motivated by their teammates to overcome impairment. Teams may benefit from the viewpoints of several individuals allowing the pooling of ideas and comparison of information before reaching a decision. Teams are also likely to contain individuals who have the skills sets required to complete the problem, or individuals who are less affected by the impairing factor. Uniquely, the group monitoring hypothesis predicts that the beneficial effects of team membership are expected to be most pronounced when impairing factors are present: among teams who do not face potentially impairing contexts, the benefits of team membership may go relatively unnoticed, or may not be required.

There are a number of reasons to expect improvements in team performance to be of greater magnitude under conditions of fatigue than under conditions of reasonable alertness. Several explanations for the negative effects of fatigue argue that the "resources" available to individuals are reduced because of lower levels of arousal and motivation (e.g., Johnson, 1982; Mikulincer et al., 1989). Groups and teams have been shown to increase arousal, task engagement effort, and motivation (see Baranski et al., 2007; Triplett, 1898; Zajonc & Sales, 1966). Some tasks require low levels of effort, and therefore require a relatively low level of cognitive resources, at least when a person is not fatigued. Performance by reasonably alert participants in such cases should be relatively high. In such a context, group membership may offer increased motivation and effort, but if sufficient levels of these factors are already present, such increases may not result in markedly improved performance. In contrast, under conditions of fatigue, the same tasks may require more effort and higher levels of engagement by both individuals and by team members. Increased motivation (because of group membership) under fatiguing circumstances could be expected to result in increases in performance. A similar argument can be made in terms of the effect of information pooling. Among reasonably alert individuals, error levels for a given task may be relatively low. Team membership may further reduce these errors, but this may not be particularly impactful on overall team performance. However, as team members become more fatigued, errors among individual team members become increasingly likely. In turn, the utility of being able to monitor the quality of judgments and potential solutions and also to reject erroneous information becomes greater. Thus, the group monitoring hypothesis predicts that, under some circumstances, the benefits of team membership will only become apparent when teams are fatigued.

A further process possibly underlying group monitoring is that fatigued team members may recognize the degree of each individual team member's impairment and rely upon the least impaired team member more than others, particularly if solutions can be clearly demonstrated (see Laughlin, 1980). Because the probability of a team having a relatively less impaired member is higher than the probability of an individual being relatively less fatigued, team performance should, on average, be superior. Thus, better performance is particularly expected among fatigued teams that contain one or more relatively less fatigued members—an individual who can act as a leader.

To date the group monitoring hypothesis has only been tested in the context of alcohol intoxication. Abrams et al. (2006) showed that individuals who had a blood alcohol concentration equivalent to the drunk driving limit in the United Kingdom made riskier decisions than individuals who received a placebo. In contrast, groups did not find risky bets attractive, regardless of whether they were intoxicated or not. There was no difference in risk perception between individuals and groups in the placebo condition. Frings et al. (2008) showed that during an auditory vigilance task intoxicated individuals had a higher error rate (over/under estimation of how many times a target word appeared) than individuals who had received a placebo. Placebo individuals also had a lower error rate than intoxicated group members who made estimates in the presence of other group members (without communication), however, the difference in error rate was significantly reduced. It is important to note that when group members had the opportunity to discuss their responses before reaching a unified decision, intoxicated groups had the same error rate as placebo individuals and placebo groups. Again, there was no difference in error rates between individuals and groups in the placebo conditions. Overall, these findings suggest that group monitoring shields group members from the effects of alcohol by increasing motivation because of evaluative pressure from other members, allowing the pooling of information, and the rejection of erroneous judgments. It also appears that these increases are more beneficial in contexts in which other impairing factors are present: there was no difference in error rates between placebo groups and placebo individuals, while there was a significant difference between intoxicated groups and intoxicated individuals.

If the group monitoring hypothesis can be applied to problem solving among fatigued teams, a number of predictions can be made. Specifically, it would be expected that there would be an increase in Einstellung and a decrease in problem solving ability among fatigued individuals, but not among fatigued teams. It can also be expected that improvements in team performance, relative to individual performance, should be particularly pronounced under conditions of fatigue. This would be reflected by little or no difference in performance between reasonably alert teams and reasonably alert individuals, and significantly better performance by fatigued teams relative to fatigued individuals.

In summary, social psychology suggests that team membership may either increase or decrease problem solving performance and levels of Einstellung. Uniquely, the group monitoring hypothesis suggests that team membership may increase performance especially under conditions where it would otherwise be impaired. The present experiment tests the effects of fatigue and team membership on problem solving ability and also Einstellung (lack of cognitive flexibility) using the "water jar" mathematical problem set outlined by Luchins and Luchins (1969; see below). It was predicted that increased fatigue would lead to decreased problem solving performance and increased Einstellung effects among individuals. However, the group monitoring hypothesis predicts that group membership can offset such impairment; thus fatigue was not predicted to lead to a decrease in problem solving ability nor to increased Einstellung among teams.

A specific process that may underlie this effect is that teams have a higher probability of containing an "able" group member who is able to perform at a high level even after experiencing sleep loss. This may be because of either higher baseline ability, or lower susceptibility to fatigue because of sleep loss. Presumably such members are able to act as a leader by being more able to solve problems and avoid Einstellung. When such members are present, it can be expected that other group members will utilize their judgments and abilities, leading to higher team level performance. To test this process, it was also hypothesized that teams with a single member who subjectively experiences lower levels of fatigue after sleep deficit would outperform teams whose least fatigued member reports higher levels of fatigue.

To test these hypotheses, problem solvers working either alone or as part of a team were asked to solve a series of mathematical problems while they were either reasonably alert or fatigued because of sleep deficit. By comparing the performance of reasonably alert and fatigued individuals (in terms of both number of problems solved and the amount of Einstellung present), the effects of fatigue can be identified. An interaction between fatigue and group membership was expected. Specifically, in line with group monitoring, it was expected that reasonably alert individuals and groups would solve a similar number of problems, and show a similar level of Einstellung. Comparing the performance of reasonably alert and fatigued groups to each other and to individuals' performance allows an assessment of the effects of team membership on fatigued performance. The group monitoring hypothesis predicts fewer solved problems and increased Einstellung among fatigued individuals (relative to reasonably alert individuals) but not among fatigued groups (relative to reasonably alert individuals and groups), indicating that team membership can offset the effects of fatigue.

Method

Participants

One hundred seventy-one Army Officer Cadets were recruited from the University of London Officer Training Corps. Ages ranged from 18 to 24. Seventy-two percent of the sample was male. Participants were randomly allocated to condition. Thirty-six participants took part as individuals (21 reasonably alert and 15 fatigued), and 135 took part as team members (21 reasonably alert teams, 13 fatigued). Differences in number of teams and individuals in the fatigued condition were because of participant withdrawal before the start of the fatigued testing session.

Design

A 2 $\times$ 2 between-subjects design was used: (Group condition: team vs. individual) $\times$ (Fatigue condition: fatigued vs. reasonably alert). Participants were randomly assigned to conditions. Participants in the team condition completed the problem-solving tasks in groups of four (except one group, which consisted of three). Team members for any particular team were drawn from the same platoon. Participants in the study had been in the same platoon for at least 6 months. The gender mix within each team was not controlled.[1] Dependent variables consisted of the number of correctly completed problems, and the number of steps taken to complete each problem. An adapted version of the Piper Fatigue Scale (Piper et al., 1998) was used as an assessment of subjectively rated fatigue levels.

Measures

Fatigue. Eight items from the original Piper Fatigue Scale were selected to rate the level of fatigue. This scale was selected because it measures fatigues across a number of domains. Specifically, it measures perceived degree of fatigue, fatigue related affect and also perceived levels of cognitive impairment attributed by the participant to fatigue (rather than to other contextual factors). Three items asked participants: "How would you describe the intensity of severity of the fatigue which you are experiencing now?", "To what degree is the fatigue you are now feeling interfering with your ability to complete tasks set for you?", and "To what degree would you describe the fatigue you are experiencing as being?" A seven-point scale was used for each item. The first two items were anchored at 1 (*None*) and 7 (*A great deal*). The latter item was anchored at 1 (*Mild*) and 7 (*Severe*). A further five items measured "To what extent are you now feeling" followed by seven point scales anchored with the following oppositional pairs; *Exhilarated/Depressed*, *Able to concentrate/Unable to concentrate*, *Strong/Weak*, *Able to remember/Unable to remember*, *Able to think clearly/Unable to think clearly*. Internal reliability of all eight items was good (Cronbach's $\alpha = .90$), and a composite mean score was calculated. Higher scores indicate increased subjective feelings of fatigue.

Problem-solving task. A series of 10 "water jug" problems drawn from Luchins and Luchins (1969) were used. These problems present the solver with four hypothetical jugs labeled A–D. The task is to reach a target volume in any jug by filling and emptying the jugs into one another. Jugs can be filled independently, or the contents of one jug can be filled with another. The target amount needs to be reached in as few steps as possible—the action of filling a jug or emptying its contents (fully or partially) into another each count as one step. For example, problem 1 (Table 1) presents jugs with the following names/volumes: A (21 L), B (127 L), C (3 L), D (89 L). In problem 1, the solver must reach a target volume of 100 L in as few steps as possible. The solution to this task is to fill jug B (step 1), empty liquid from B into A (step 2), empty more liquid from B into C (step 3) and then again empty more liquid from B into C (step 4). At this point, jar B contains the target amount (100 L). The first five problems can be solved using this formula B-A-2C (or with different jar combinations e.g., D-A-2B). The first 5 problems comprise the *training problems*, and no shorter solutions exist. Once the solution is found, it is relatively easy to apply to the subsequent problems.

Problems 6, 7, 9, and 10 comprise the *critical problems*. Einstellung is measured by measuring how participants solve the critical problems. Critical problems can be solved with the already established 4 step B-A-2C formula (nonoptimal solution) or by a more direct A-C or A + C method (optimal solutions) in 2 steps ("Fill A," "Fill C from A"). Solvers who, on average, choose to use the 4-step problem more often than the 2-step problem are failing to switch strategies, and are said to be experiencing Einstellung. Mean steps can range from 2 (*no Einstellung, solver always switches strategy*) to 4 (*complete Einstellung, solver never switches*).

The eighth problem, named the *extinction problem*, cannot be solved with B-A-2C, but can with A-C. This problem is important as it cues participants who solve it toward the more optimal two step strategy. This means that, as well as comparing number of steps during the *critical problems* as a whole, the number of steps taken on average for problems 9 and 10 can be compared. Failure to switch strategies after the extinction problem shows Einstellung is well established, because solvers revert to original nonoptimal strategies after the optimal solution has been highlighted.

Participants were given the following instructions before starting the task: "You will be asked to imagine that you have 4 jugs, each with set volumes. You can fill each jug up or empty it as many times as you choose. *Your job is to reach the required volume in as few moves as possible*. You will have 1 minute to do each question. Once you have completed a question, please wait until the experimenter tells you to turn the page before you start the next one." An example problem (with a different completion strategy to those in the task) was also presented. Team members were instructed to work as a team.

[1] Although gender was not controlled for when assigning participants, χ^2 analysis revealed that men and women were randomly distributed across condition, $\chi^2(3) = 4.54$, $p = .21$. In addition, the number of females in a group did not systematically differ across conditions, ($p = .43$, Fisher's exact test).

Table 1
Water Jar Problems (Drawn From Luchins and Luchins, 1969)

Problem	Capacity of each jug: Jug A	Jug B	Jug C	Jug D	Target volume
1.	21	127	3	89	100
2.	14	163	25	43	99
3.	18	43	10	27	5
4.	9	42	6	36	21
5.	20	59	4	22	31
6.	23	49	3	15	20
7.	15	39	3	16	18
8.	28	76	3	37	25
9.	18	48	4	16	22
10.	14	36	8	4	6

Note. Each problem consists of four jugs of various capacities. Water can be poured from one jug to any other. The aim of each problem is to reach the target volume in any jug in as few steps as possible.

Participants were then presented with the first problem on paper and asked to complete it. Once 1 min had elapsed, they were instructed to begin work on the next problem, and so on, until the first four problems had been completed. Participants recorded their solutions to each problem on the paper provided. They then completed a distracter task (a face recognition task lasting seven minutes) before completing the remaining 6 problems. This distracter task was included to ensure that participants did not experience too much Einstellung, which would have resulted potentially in ceiling effects. Previous research has shown that breaks from problem solving can encourage new approaches when problem solving is resumed (Sio & Ormerod, 2009; Smith & Blankenship, 1991). Before completing the remaining six problems, the instructions were presented again verbally and in writing.

Procedure

The study took place over the course of one weekend during a winter training exercise in England. All participants arrived in the exercise area on Friday evening. They had not had any special interventions to their sleep patterns during the week, and had been told to be well rested before the exercise by their officers. The task was undertaken in study rooms.

Participants in the reasonably alert condition completed the study upon arrival in the training exercise area on Friday evening (around 7 p.m.). Participants in the fatigued condition completed the task around 10:00–11:00 a.m. on Sunday morning. Between arrival and testing, as part of their scheduled training, participants in the fatigue condition were subjected to intensive teaching, vigorous exercise, and systematically disturbed sleep (sleep duration of 5 hours or less per night, and being woken up during this period for an hour of watch duty each night), all in cold, rainy, outdoor conditions.

Upon arrival at the testing facility, all participants gave consent and completed the fatigue scale. They then completed the problem-solving tasks (as outlined earlier) as part of a test battery. Once the tasks were completed, participants were dismissed into the care of their officers. Debriefing followed after all participants had had an opportunity to nap.

Results

Analytical Strategy

As outlined earlier, group monitoring can be argued to exist if fatigue decreases performance among individuals but does not affect teams. In addition, individuals who are reasonably alert should perform at a level similar to reasonably alert teams. To compare teams and individuals who were fatigued or alert, a between-subjects analysis of variance (ANOVA) approach was selected. Unless otherwise stated, ANOVAs were conducted with fatigue condition (fatigued vs. reasonably alert) and group condition (team vs. individual) as independent variables.

Fatigue. ANOVA conducted on the adapted version of the Piper Fatigue Scale revealed that participants reported higher levels of fatigue in the fatigued condition than in the reasonably alert condition ($M_{fat} = 4.66$, $SD_{fat} = 1.56$ vs. $M_{alert} = 3.66$, $SD_{alert} = 1.49$), $F(1, 158) = 8.23$, $p = .005$, $\eta^2 = .05$. No main effect of group condition or interactions were present, $ps > .50$. This suggests that, as expected, participants felt more subjectively fatigued in the fatigued condition than in the reasonably alert condition. In addition, the absence of an interaction shows that there were no differences in fatigue levels between reasonably alert individuals and reasonably alert teams, or between fatigued individuals and fatigued teams.

Problem completion. All analysis of problem solving performance treated each team as a single data point. ANOVA on total number of problems solved revealed that teams completed more problems ($M_{team} = 8.05$, $SD_{team} = 1.58$) than individuals ($M_{ind} = 5.03$, $SD_{ind} = 2.02$), $F(1, 66) = 45.71$, $p < .001$, $\eta^2 = .41$. There was no difference in the number of problems solved by fatigued and reasonably alert participants, ($M_{fat} = 6.04$, $SD_{fat} = 2.33$ vs. $M_{alert} = 6.81$, $SD_{alert} = 2.36$), $p = .14$. There was no significant interaction between group condition and fatigue condition, $p = .91$. This suggests that team membership increased the number of problems solved correctly regardless of fatigue condition. Fatigue, however, had no effect on the number of problems solved.

A second ANOVA revealed that neither fatigue nor team membership had any effect on the completion rate of the extinction problem, independently or interactively, $ps > .086$. This suggests that completion rate for this particular problem was unaffected by the manipulations.

Presence of Einstellung. Einstellung is reflected by a failure to switch between the 4-step solution used in the *training problems* to the 2-step solution possible in the *critical problems*. To calculate mean number of steps used during critical problems, the total number of steps for correctly solved critical problems was divided by the number of correctly solved critical problems. To recap, a mean score of 2.00 represents an optimal response with no Einstellung (solver always switches strategy) and scores over 2 represent increasing levels of Einstellung. The highest possible mean score is 4, representing a total failure to switch strategies.

ANOVA revealed no main effect of group or fatigue condition, $ps > .30$. However the predicted interaction between fatigue and group condition was significant, $F(1, 66) = 5.61$, $p = .021$, $\eta^2 = .08$. Means can be seen in Table 2 and Figure 1. Simple effects analysis revealed that individuals took more steps to solve critical problems when fatigued, $M_{fat\_ind} = 2.56$, $SD_{fat\_ind} = .78$ versus $M_{alert\_ind} = 2.18$, $SD_{alert\_ind} = .39$, $F(1, 66) = 4.18$, $p = .045$, $\eta^2 = .06$. In the

Table 2
Mean Number of Steps During Critical Problems and Post Extinction Problems, According to Group and Fatigue Condition

		Group condition	
Problem type	Fatigue condition	Individual	Team
Critical problems	Reasonably alert	2.18 (.40)$_a$	2.36 (.59)
	Fatigued	2.56 (.78)$_{ab}$	2.10 (.28)$_b$
Post extinction	Reasonably alert	2.18 (.38)$_c$	2.36 (.61)
	Fatigued	2.69 (1.23)$_{cd}$	2.15 (.38)$_d$

Note. SDs in parentheses. Mean sharing a subscript differ with the following levels of significance: a, $p = .045$; b, $p = .032$; c, $p = .04$; and d, $p = .05$.

fatigued condition, teams took on average less steps to solve the critical problems than individuals, $M_{fat\_team} = 2.10$, $SD_{fat\_team} = .28$ versus $M_{fat\_ind} = 2.56$, $SD_{fat\_ind} = .78$, $F(1, 66) = 4.80$, $p = .032$, $\eta^2 = .07$. Remaining simple effects were nonsignificant, *p*s > .19. As the lack of a difference between fatigued and reasonably alert participants is a fundamental test of the group monitoring hypothesis, power analysis was undertaken for this comparison. This revealed the sample sizes involved in this comparison ($n = 13$ vs. $n = 20$) lead to a power of .71 to detect a large effect.

In summary, these findings suggest that reasonably alert individuals and teams did not differ in the number of steps they took to solve critical problems. Fatigued individuals took more steps (i.e., demonstrated more Einstellung) when solving the critical problems than reasonably alert individuals. Crucially for the group monitoring hypothesis, fatigued teams completed critical problems using no more steps than reasonably alert teams and individuals, and fewer than fatigued members, showing they did not experience increased Einstellung.

Analysis of the two problems posed after the *extinction problem* (which cues problem solvers to the optimal 2-step solution) showed no main effects of group or fatigue conditions, *p*s > .31, but a significant interaction, $F(1, 63) = 4.31$, $p = .04$, $\eta^2 = .06$.

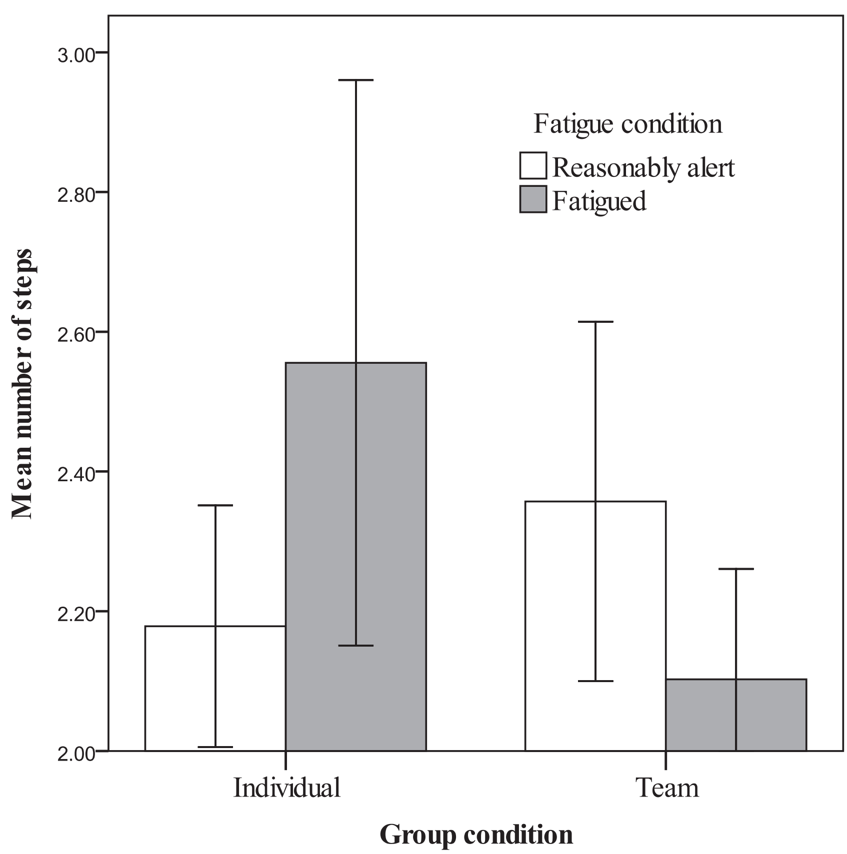

Figure 1. Mean number of steps during critical problems, according to group and fatigue condition. Two steps is the minimum (and optimal) number with which problems can be solved. Error bars represent *SE* +/− 2.

As can been seen in Table 2, individuals took more steps on average to solve these problems when fatigued, $M_{fat\_ind} = 2.69$, $SD_{fat\_ind} = 1.23$ versus $M_{alert\_ind} = 2.18$, $SD_{alert\_ind} = .38$, $F(1, 63) = 4.40$, $p = .040$, $\eta^2 = .07$. In the fatigued condition, teams used fewer steps than individuals ($M_{fat\_team} = 2.15$, $SD_{fat\_team} = .38$ vs. $M_{fat\_ind} = 2.69$, $SD_{fat\_ind} = 1.23$), $F(1, 63) = 3.93$, $p = .05$, $\eta^2 = .06$. Remaining simple effects were nonsignificant, $p\text{s} > .40$. This shows that, even when fatigued individuals were cued toward the optimal 2-step solution, they were more likely than any other condition to return to the 4-step solution for the last two critical problems. Fatigued teams used on average the same number of steps as reasonably alert teams and individuals after being cued.

One process that may partly underlie group monitoring is that teams may contain individuals who are less susceptible to fatigue and are less impaired, and thus can lead the team toward better performance, for instance by avoiding Einstellung. To test the hypothesis that team members rely on their least impaired member, each team was assigned the lowest score on the adapted version of the Piper Fatigue Scale reported by any of its members. Regression analysis revealed that the lowest fatigue score was significantly related to fewer steps being taken in correctly solved critical problems, $R^2 = .14$, $\beta = -.38$, $t(31) = 2.27$, $p = .03$, and correctly solved postextinction critical problems, $R^2 = .17$, $\beta = -.41$ $t(31) = 2.53$, $p = .017$. This suggests that the teams that contained individual members with lower levels of fatigue experienced less Einstellung than teams whose least impaired member was more fatigued.

Discussion

Fatigue caused by sleep deficit has been shown previously by numerous other researchers to have a deleterious effect upon cognitive skills in a variety of domains. To date, no research has investigated the effects of fatigue upon Einstellung (lowered cognitively flexibility) sometimes witnessed in problem-solving situations. The findings of the present study demonstrate, for the first time, that fatigue can induce increased Einstellung in problem solving: Fatigued individuals were, on average, more likely to fail to switch problem-solving strategies than reasonably alert individuals (reflected by using more steps to complete critical problems). This effect remained even once participants were cued toward more optimal strategies. This suggests that Einstellung is a risk factor that fatigued problem solvers may be particularly sensitive to, and that once Einstellung is present, it may be difficult to overcome.

The present study also investigated whether team membership affects the relationship between fatigue and performance. Results showed that teams solved more problems than individuals regardless of fatigue levels, suggesting team membership can help increase performance during such tasks. There was no effect of fatigue on the absolute number of problems solved. However, inspection of the *way* problems were solved revealed a clear effect of fatigue, and a moderating effect of team membership: Fatigued individuals experienced increased Einstellung relative to reasonably alert individuals but this effect was not observed in the team conditions.

Taken together, the present findings show that although fatigue did not affect how *many* problems were solved, it did affect the *quality* of the solutions reached by increasing Einstellung among problem solvers working alone. In applied settings this is an important distinction: The "best" solution is preferable to the last/most common solution used, and in contexts where decisions have long term ramifications, failing to identify better alternatives can be costly. For instance, choosing a medical treatment regimen with which one is familiar but is known to have side effects while failing to identify better alternatives could lead to considerable patient distress. Using a navigational or military strategy that appears suitable but does not consider alternatives could lead to longer journey times or increased causalities. It is important to note that the present study showed that while fatigued problem solvers working alone had increased Einstellung, those working in teams did not experience increased Einstellung as a result of fatigue.

One explanation as to why teams may not experience increased Einstellung when fatigued is offered by the *group monitoring hypothesis*. Uniquely, this predicts not only that team membership can improve performance, but also that benefits of team membership should be particularly pronounced under conditions of impairment from factors such as fatigue. When individuals and teams perform at similar levels when reasonably alert, and individuals (but not teams) are affected by fatigue, group monitoring can be said to be occurring. The group monitoring hypothesis received mixed support from the present study. Teams consistently completed more problems than individuals when both fatigued and alert, suggesting a general advantage of team membership for this dimension of performance, regardless of levels of impairment. However, importantly from a group monitoring perspective, performance measured by ability to switch strategies and find efficient solutions to problems (indicating avoidance of Einstellung) exhibited a more complex pattern. Decreases in such performance under conditions of fatigue were only observed among individuals: fatigued individuals experienced significantly more Einstellung than both reasonably alert individuals and fatigued/alert teams. In contrast, team performance was unaffected by fatigue. In the reasonably alert conditions, teams and individuals were equally proficient at switching strategies. This suggests that while gross measures of performance (number of problems solved) may show a clear pattern of social facilitation (improved performance because of team membership) regardless of fatigue condition, closer analysis reveals that some benefits of team membership (less/no increase in Einstellung) occur only when teams were fatigued, as predicted by group monitoring.

To date, the group monitoring hypothesis has been applied to vigilance tasks (Frings et al., 2008), and also to risk assessment (Abrams et al., 2006) both under conditions of alcohol intoxication. The present research extends this body of work by applying group monitoring to problem solving while fatigued because of sleep deficit. It also begins to test possible processes underlying group monitoring—the possibility that teams will recognize and rely upon more able members who can lead the team when fatigued. In the present study, the lowest level of subjective fatigue reported by any team member within the group predicted the degree of Einstellung experienced by the team as a whole. This novel finding extends group monitoring by suggesting that team members are able to recognize how impaired their individual members are, subsequently relying to a greater extent upon less impaired members to solve problems. This has an important implication for group monitoring as it implies that more impaired team members receive greater benefit from team membership than those who are less impaired.

The present research compliments and extends the little existing literature investigating group processes under conditions of fatigue. Baranski et al. (2007) demonstrated social facilitation can help fatigued groups, however, they did not examine whether such facilitation occurred when all group members were engaged interactively with the opportunity for unconstrained communication. The present study suggests that team membership can also offset fatigue in such contexts. The current findings also compliment Hoeksema et al. (1998) who observed that social loafing in fatigued teams was reduced when team members were accountable via potential feedback to other members. In the present study, the physical proximity and highly collaborative nature of the task should lead to high levels of accountability between team members. Where Hoeksema observed a reduction in social loafing under moderate levels of accountability, the current study (with higher levels of accountability) reports increases in performance. Taken together, these findings and those of Hoeksema confirm that teams will work more effectively to the extent individual team members are accountable to their fellow team members, and that such accountability may be particularly important under conditions were team members are fatigued.

There are several limitations to the present research and these suggest avenues for future research. Participants had a moderate, but not severe, sleep deficit and a consummate increase in subjective feelings of fatigue. However, the levels of sleep deficit in the present study are comparable to those commonly found in workplace settings and were sufficient to impair individual performance by increasing Einstellung. The task used was also relatively simple. Whether group monitoring occurs during more demanding tasks and under contexts of increased impairment is an open question. One possibility is that, provided teams are not so impaired that they cannot coordinate their actions, group monitoring will occur. However, when teams become too impaired to coordinate their actions, increased deindividuation and social loafing may occur. Similarly, it is possible that as long as a single team member or the combined efforts of the team is capable of the task group monitoring should occur. However, if the task becomes too difficult, team membership may actually hinder performance. Future research could address this by manipulating task difficulty and degree of impairment.

A further consideration is how well the team members knew one another prior to the start of the present study (teams were formed from cadet members of a military platoon who knew one another and previously worked together for at least 6 months). This may limit the extent to which the present research generalizes to groups as well as teams. Using groups with no prior history allows group processes to be examined independently of existing intrateam relationships or knowledge (for instance, participants' knowledge of other group members' abilities and expertise). When teams are studied, a number of processes may also operate that may not be present in groups. For instance, team members who are fatigued may rely more upon estimates of other team members whom they know to be more proficient. Likewise, team members who are perceived to be less proficient may be increasingly marginalized in the decision making process under conditions of impairment, regardless of their accuracy. The evidence that the level of fatigue of the least fatigued team member predicted Einstellung in the present study supports this possibility. To investigate this, future research could measure perceived competence, or systematically manipulate it between teams.

One key factor in fatigue that was not controlled for in the present study was the presence of circadian rhythm effects. Task performance among humans typically varies over the course of the day because of the endogenous body clock. Circadian rhythms influence body temperature, alertness and feelings of sleepiness independently of sleep deficit (see Czeisler, Weitzman, Moore-Ede, Zimmerman, & Kronauer, 1980). Circadian-related sleepiness typically increases from the 7:30 p.m. onward, with the deepest trough in alertness and body temperature observed between 2 a.m. and 5 a.m. (see Lavie, 1991). A second lesser trough occurs between 2 p.m. and 5 p.m. In the present study, participants in the reasonably alert condition were tested in the evening, after the afternoon trough had passed, before the nighttime decline in alertness began. In the fatigue condition, participants were tested midmorning, again between circadian troughs in sleepiness. If fatigued participants had been tested earlier in the morning (e.g., 4 a.m.) even higher levels of sleepiness and lower levels of alertness would have been expected.

A second related circadian factor that could be considered is individual differences in fatigue susceptibility. Some individuals show extremely high levels of sleepiness and low levels of alertness after only minimal sleep loss, while others are relatively immune to significantly greater losses (Van Dongen, Vitellaro, & Dinges, 2005). The present study argues that teams are more likely to contain individuals who are less susceptible to fatigue, and thus more able to complete tasks. As well as general susceptibility to fatigue, the endogenous body clock also shows significant individual variation, often conceptualized as a dimension between "morning" and "evening" types. Morning types are more alert in the morning and more affected by sleep disruption, while evening types are less alert in the morning, wake up later and go to bed later (see, for example, Bailey & Heitkemper, 2001; Duffy, Dijk, Hall, & Czeisler, 1999; Gaina et al., 2006). An alternative (but similar) interpretation of the current findings could be that teams are more likely to contain individuals who at the particular time of testing are most alert at that time of day. Such individuals would be expected to perform better, and help the team counter fatigue. To test this explanation, future research could control for individual differences in circadian rhythm, or systematically manipulate team composition.

That fatigue can lead to Einstellung is an important finding for various industries and highlights risks and potential solutions. For instance, Einstellung during medical diagnosis can lead to possible misdiagnosis. Military decision makers experiencing Einstellung may overlook potential risks and opportunities in changing situations (see Cañas et al., 2003; Miller et al., 2008). The present study suggests that, wherever practical, such tasks are worked on by teams rather than individuals. This could be implemented in a number of ways, for instance by formalizing consultation periods with other members of the team as part of the decision making process, or ensuring that problem solvers work in teams when fatigued. If it is wholly impractical to have problems solved by teams, then organizations should seek to identify problem situations in which Einstellung is particularly likely to occur or be particularly impactful. Problem solvers can then be taught to consider the effects Einstellung may have upon their decisions in such situations, and hopefully delay taking the decision if warranted.

In conclusion, the present study shows, for the first time, that fatigue can result in Einstellung (cognitive inflexibility). In addition, it provides supporting evidence for the group monitoring hypothesis. Although fatigued individuals experienced increased Einstellung, this effect was not found among teams. In line with the group monitoring hypothesis, this advantage of team membership was only experienced under conditions of fatigue. This research suggests that tasks undertaken while fatigued are best carried out in teams, to the extent to which team membership can offset fatigue related Einstellung.

References

Abrams, D., Hopthrow, T., Hulbert, L., & Frings, D. (2006). "Groupdrink"? The effect of alcohol on risk attraction among groups versus individuals. *Journal of Studies on Alcohol, 6,* 628–636.

Abrams, D., Wetherell, M., Cochrane, S., Hogg, M. A., & Turner, J. (1990). Knowing what to think by knowing who you are: Self-categorization and the nature of norm formation, conformity and group polarization. *British Journal of Social Psychology, 29,* 97–119. doi:10.1111/j.2044-8309.1990.tb00892.x.

Bailey, S., L., & Heitkemper, M. M. (2001). Circadian rhythmicity of cortisol and body temperature: Morningness-eveningness effects. *Chronobiology International, 18,* 249–261. doi:10.1081/CBI-100103189.

Baranski, J. V., Thompson, M. M., Lichacz, F. M. J., & McCann, C. G. (2007). Effects of sleep loss on team decision making: Motivational loss or motivational gain? *Human Factors, 49,* 646–660. doi:10.1518/001872007X215728.

Biggs, S., Smith, A., Dawson, D., van den Heuvel, C., Dorrian, J., Reid. K., & Baulk, S. D. (2007). Subjective sleepiness and driving performance: Can sleepy drivers accurately predict driving performance after caffeine? *Journal of Psychosomatic Research, 63,* 573–577. doi:10.1016/j.jpsychores.2007.06.017.

Bilalić, M., McLeod, P., & Gobet, F. (2008). Why good thoughts block better ones: The mechanism of the pernicious Einstellung (set) effect. *Cognition, 108,* 652–661. doi:10.1016/j.cognition.2008.05.005.

Bilalić, M., McLeod, P., & Gobet, F. (2010). The mechanism of the Einstellung (set) effect: A pervasive source of cognitive bias. *Current Directions in Psychological Science, 19,* 111–115. doi:10.1177/0963721410363571.

Caldwell, J. A., Mallis, M. M., Caldwell, J. L., Miller, J. C., & Neri, D. F. (2009). Fatigue countermeasures in aviation. *Aviation, Space, And Environmental Medicine, 80,* 29–59. doi:10.3357/ASEM.2435.2009.

Cañas, J. J., Quesada, J. F., Antolí, A., & Fajardo, I. (2003). Cognitive flexibility and adaptability to environmental changes in dynamic complex problem-solving tasks. *Ergonomics, 46,* 482–501. doi:10.1080/0014013031000061640.

Czeisler, C. A., Weitzman, E. D., Moore-Ede, M. C., Zimmerman, J. C., & Kronauer, R. S. (1980). Human sleep: Its duration and organization depend on its circadian phase. *Science, 210,* 1264–1267. doi:10.1126/science.7434029.

Duffy, J. F., Dijk, D. J., Hall, E. F., & Czeisler, C. A. (1999). Relationship of endogenous circadian melatonin and temperature rhythms to self-reported preference for morning or evening activity in young and older people. *Journal of Investigative Medicine, 47,* 141–150.

Ferguson, S. A., Paech, G. M., Dorrian, J., Roach, G. D., & Jay, S. M. (2011). Performance on a simple response time task: Is sleep or work more important for miners? *Applied Ergonomics, 42,* 2010–2213. doi:10.1016/j.apergo.2010.06.010.

Frings, D., Hopthrow, T., Abrams, D., Hulbert, L., & Gutierrez, R. (2008). Groupdrink: The effects of alcohol on a group vigilance task. *Group Dynamics, 12,* 179–190. doi:10.1037/1089-2699.12.3.179.

Gaina, A., Sekine, M., Kanayama, H., Takashi, Y., Hu, L., Sengoku, K., & Kagamimori, S. (2006). Morning evening preference: Sleep pattern spectrum and lifestyle habits among Japanese junior high school pupils. *Chronobiology International, 23,* 607–621. doi:10.1080/07420520600650646.

Gander, P., Millar, M., Webster, C., & Merry, A. (2008). Sleep loss and performance of anaesthesia trainees and specialists. *Chronobiology International, 25,* 1077–1091. doi:10.1080/07420520802551428.

Gastorf, J. W., Suls, J., & Sanders, G. S. (1980). Type A coronary-prone behavior pattern and social facilitation. *Journal of Personality and Social Psychology, 38,* 773–780. doi:10.1037/0022-3514.38.5.773.

Geen, R. G. (1989). Alternative conceptions of social facilitation. In P. B. Paulus (Ed.), *Psychology of group influence* (2nd ed., pp. 15–51). Hillsdale, NJ: Erlbaum, Inc.

Harries, C., Yaniv, I., & Harvey, N. (2004). Combining advice: The weight of a dissenting opinion in the consensus. *Journal of Behavioral Decision Making, 17,* 333–348. doi:10.1002/bdm.474.

Hart, J. W., Karua, S. J., Stasson, M. F., & Kerr, N. A. (2004). Achievement motivation, expected coworker performance, and collective task motivation: Working hard or hardly working? *Journal of Applied Social Psychology, 34,* 984–1000. doi:10.1111/j.1559-1816.2004.tb02580.x.

Haslam, D., & Abraham, P. (1987). Sleep loss and military performance. In G. Belenky (Ed.), *Contemporary studies in combat psychiatry* (pp. 167–184). New York, NY. Greenwood.

Hill, G. W. (1982). Group versus individual performance: Are N_1 heads better than one? *Psychological Bulletin, 91,* 517–539. doi:10.1037/0033-2909.91.3.517.

Hoeksema-van Orden, C. Y. D., Gaillard, A. W. K., & Buunk, B. P. (1998). Social loafing under fatigue. *Journal of Personality and Social Psychology, 75,* 1179–1190. doi:10.1037/0022-3514.75.5.1179.

Hogg, M. A. (2001). A social identity theory of leadership. *Personality and Social Psychology Review, 5,* 184–200. doi:10.1207/S15327957PSPR0503_1.

Johnson, D. W., & Johnson, F. P. (1987). *Joining together: Group theory and group skills* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.

Johnson, L. C. (1982). Sleep deprivation and performance. In W. W. Webb (Ed.), *Biological rhythms, sleep and performance*. New York: Wiley.

Karau, S. J., & Williams, K. D. (1993). Social loafing: A meta-analytic review and theoretical integration. *Journal of Personality and Social Psychology, 65,* 681–706. doi:10.1037/0022-3514.65.4.681.

Kilgore, W. D., Grugle, N. L., Kilgore, D. B., Leavitt, B. P., Watlington, G. I., McNair., S. & Balkin, T. J. (2008). Restoration of risk-propensity during sleep deprivation: Caffeine, dextroamphetamine, and modafinil. *Aviation, Space and Environmental Medicine, 79,* 867–874. doi:10.3357/ASEM.2259.2008.

Krueger, G. P. (1989). Sustained work, fatigue, sleep loss and performance: A review of the issues. *Work and Stress, 3,* 129–141. doi:10.1080/02678378908256939.

Lamond, N., & Dawson, D. (1999). Quantifying the performance impairment associated with fatigue. *Journal of Sleep Research, 8,* 255–262. doi:10.1046/j.1365-2869.1999.00167.x.

Landrigan, C., Rothschild, J., Cronin, J. W., Kaushal, R., Burdick, E., Katz, J. . . . Bates, D. W. (2004). Effect of reducing interns' work hours on serious medical errors in intensive care units. *New England Journal of Medicine, 351,* 1838–1848. doi:10.1056/NEJMoa041406.

Laughlin, P. R. (1980). Social combination processes of cooperative problem solving groups on verbal intellective tasks. In M. Fishbein (Ed.), *Progress in social psychology* (pp. 127–155). Hillsdale, NJ: LEA.

Laughlin, P. R., Hatch, E., Silver, J., & Boh, L. (2006). Groups perform better than the best individuals on letters-to-numbers problems: Effects of group size. *Journal of Personality and Social Psychology, 90,* 644–651. doi:10.1037/0022-3514.90.4.644.

Lavie, P. (1991). The 24-hour sleep propensity function (SPF): Practical and theoretical implications. In T. H. Monk (Ed.), *Sleep, sleepiness and performance* (pp. 65–93). Oxford, England: Wiley.

Lim, J., & Dinges, D. F. (2010). A meta-analysis of the impact of short-term sleep deprivation on cognitive variables, *Psychological Bulletin, 136,* 375–389. doi:10.1037/a0018883.

Luchins, A. S. (1942). Mechanization in problem solving: The effect of Einstellung. *Psychological Monographs, 54,* 1–95.

Luchins, A. S., & Luchins, E. H. (1969). Einstellung effect and group problem solving. *Journal of Social Psychology, 77,* 79–89. doi:10.1080/00224545.1969.9919848.

Marine Accident Investigation Board. (2004). *Bridge watchkeeping safety study*. Retrieved from http://www.maib.gov.uk/cms_resources/Bridge_watchkeeping_safety_study.pdf

Marques, J., Abrams, D., & Serodio, R. G. (2001). Being better by being right: Subjective group dynamics and derogation of in-group deviants when generic norms are undermined. *Journal of Personality and Social Psychology, 81,* 436–447. doi:10.1037/0022-3514.81.3.436.

McGrath, J. E. (1984). *Groups: Interaction and performance.* Englewood Cliffs, NJ: Prentice Hall.

Mikulincer, M., Babkoff, H., Caspy, T., & Sing, H. (1989). The effects of sleep loss on psychological variables. *British Journal of Psychology, 80,* 145–162. doi:10.1111/j.2044-8295.1989.tb02309.x.

Miller, N. L., Matsangas, P., & Shattuck, L. G. (2008). Fatigue and its effect on performance in military environments. In P. A. Hancock & J. L. Szalma (Eds.), *Performance under stress* (pp. 231–249). Hampshire, England: Ashgate Publications.

Muller, D., & Butera, F. (2007). The focusing effect of self-evaluation threat in coactions and social comparison, *Journal of Personality and Social Psychology, 93,* 194–211. doi:10.1037/0022-3514.93.2.194.

Muller, D., & Fayant, M. P. (2010). On being exposed to superior others: Consequences of self-threatening upward social comparisons. *Social and Personality Compass, 4,* 621–634. doi:10.1111/j.1751-9004.2010.00279.x.

Neri, D. F., Oyung, R. L., Colletti, L. M., Mallis, M. M., Tam, P. Y., & Dinges, D. F. (2002). Controlled breaks as a fatigue countermeasure on the flight deck. *Aviation, Space, and Environmental Medicine, 73,* 654–664.

Noy, Y. I., Horrey, W. J., Popkin, S. M., Folkard, S., Howarth, H. D., & Courtney, T. K. (2011). Future directions in fatigue and safety research. *Accident Analysis and Prevention, 43,* 495–497. doi:10.1016/j.aap.2009.12.017.

Papp, K., K., Stoller, E. P., Sage, P., Aikens, J. E., Owens, J., Avidan, A., . . . Strohl, K. P. (2004). The effects of sleep loss and fatigue on resident-physicians: A multi-institutional, mixed-method study. *Academic Medicine, 79,* 394–406. doi:10.1097/00001888-200405000-00007.

Piper, B. F., Dibble, S. L., Dodd, M. J., Weiss, M. C., Slaughter, R. E., & Paul, S. M. (1998). The revised Piper Fatigue Scale: Psychometric evaluation in women with breast cancer. *Oncological Nursing Forum, 25,* 677–684.

Rabinbach, A. (1990). *The human motor: Energy, fatigue, and the origins of modernity.* New York, NY: Basic Books.

Schultz, P. W., & Searleman, A. (1998). Personal need for structure, the Einstellung task, and the effects of stress. *Personality and Individual Differences, 24,* 305–310. doi:10.1016/S0191-8869(97)00179-7.

Sherif, M. (1936). *The psychology of social norms.* Oxford, England: Harper.

Sio, U. N., & Ormerod, T. C. (2009). Does incubation enhance problem solving? A meta-analytic review. *Psychological Bulletin, 135,* 94–120. doi:10.1037/a0014212.

Smith, S. M., & Blankenship, S. E. (1991). Incubation and the persistence of fixation in problem solving. *The American Journal of Psychology, 104,* 61–87. doi:10.2307/1422851.

Steiner, I. (1972). *Group process and productivity.* New York, NY: Academic Press.

Swezey, R. W., & Salas, E. (1992). *Teams: Their training and performance.* Norwood, NJ: Ablex.

Triplett, N. (1898). The dynamogenic factors in pacemaking and competition. *American Journal of Psychology, 9,* 507–533. doi:10.2307/1412188.

van der Linden, D., Frese, M., & Meijman, T. F. (2003). Mental fatigue and the control of cognitive processes: Effects on perseveration and planning. *Acta Psychologica, 113,* 45–65. doi:10.1016/S0001-6918(02)00150-6.

Van Dongen, H. P. A., & Maislin, G. (2003). The cumulative cost of additional wakefulness: Dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep: Journal of Sleep and Sleep Disorders Research, 26,* 117–126.

Van Dongen, H. P. A., Vitellaro, K. M., & Dinges, D. F. (2005). Individual differences in adult human sleep and wakefulness: Leitmotif for a research agenda. *Sleep: Journal of Sleep and Sleep Disorders Research, 28,* 479–496.

Williamson, A. M., & Feyer, A.-M. (2000). Moderate sleep deprivation produces comprehensive cognitive and motor performance impairments equivalent to legally prescribed levels of alcohol intoxication. *Occupational and Environmental Medicine, 57,* 649–655. doi:10.1136/oem.57.10.649.

Yaniv, I. (2004). The benefit of additional opinions. *Current Directions in Psychological Science, 13,* 75–78. doi:10.1111/j.0963-7214.2004.00278.x.

Yegneswaran, B., & Shapiro, C. (2007). Do sleep deprivation and alcohol have the same effects on psychomotor performance? *Journal of Psychosomatic Research, 63,* 569–572. doi:10.1016/j.jpsychores.2007.06.020.

Zajonc, R. B., & Sales, S. M. (1966). Social facilitation of dominant and subordinate responses. *Journal of Experimental Social Psychology, 2,* 160–168. doi:10.1016/0022-1031(66)90077-1.

Received September 22, 2010
Revision received May 17, 2011
Accepted July 11, 2011 ■