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Witnesses in Action: The Effect of Physical Exertion on Recall and Recognition

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Abstract

Understanding memory performance under different operational conditions is critical in many occupational settings. To examine the effect of physical exertion on memory for a witnessed event, we placed two groups of law-enforcement officers in a live, occupationally relevant scenario. One group had previously completed a high-intensity physical-assault exercise, and the other had not. Participants who completed the assault exercise showed impaired recall and recognition performance compared with the control group. Specifically, they provided significantly less accurate information concerning critical and incidental target individuals encountered during the scenario, recalled less briefing information, and provided fewer briefing updates than control participants did. Exertion was also associated with reduced accuracy in identifying the critical target from a lineup. These results support arousal-based competition accounts proposing differential allocation of resources under physiological arousal. These novel findings relating to eyewitness memory performance have important implications for victims, ordinary citizens who become witnesses, and witnesses in policing, military, and related operational contexts.

Keywords

eyewitness memory, memory, physical exertion, law enforcement, fatigue, policing

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Does physical activity facilitate or impede eyewitness memory? Law-enforcement officers, military personnel, and emergency responders are often involved in incidents that not only are cognitively demanding but also require bouts of intense physical activity (e.g., a chase on foot or a physical encounter). Citizens who become victims of crime may also physically exert themselves during an assault or an attempt to flee. Understanding how memory performs under such witnessing conditions is important for at least two reasons. First, detailed recall of perpetrators can protect the safety of occupational witnesses, such as law-enforcement officers and military personnel, and innocent or civilian bystanders during real-world incidents. Second, reliable statements and identifications provided by occupational witnesses, ordinary citizens, and crime victims make a significant contribution to the delivery of justice. In spite of these facts, research has not directly examined the memory performance of witnesses after physical exertion.

The literature on physiology and human performance presents a complex picture of the effects of exertion on cognition. Although physical activity can facilitate lower-level cognitive processing, as reflected in reaction times, during and after exertion (see Audiffren, 2009, for a review), the reported effects of physical activity on higher-level cognitive processes, such as memory and executive function, are more complex and often contradictory (Coles & Tomporowski, 2008; Lambourne, Audiffren, & Tomporowski, 2010).

In a recent meta-analytic comparison, McMorris, Sproule, Turner, and Hale (2011) noted that acute exercise of intermediate intensity strongly facilitates response speed for working memory tasks but is moderately detrimental to memory accuracy. McMorris and his colleagues proposed that impaired accuracy on tasks performed during and after exercise may be due to increased *neural noise* (a possible outcome of arousal-related increases in concentrations of neurotransmitters). Other researchers have observed more generalized memory impairment following high-intensity physical arousal and have concluded that such findings reflect a lack of available processing resources (i.e., an attentional account; Libkuman, Nichols-Whitehead, Griffith, & Thomas, 1999).

Accounts of this exercise-cognition interaction tend to draw on models that conceptualize physical activity as a

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stressor leading to increased arousal levels as activity increases (e.g., Sanders, 1983). These models typically predict an inverted-U effect, in which cognitive performance is poor under low-intensity exercise but improves when an optimal level of arousal is reached. At beyond-optimal arousal levels, these models predict impaired cognitive performance. In the current research, we did not aim to evaluate competing accounts of the effects of exertion on memory. However, the arousal account offers a general framework for interpreting witnesses' memory performance during or shortly after exertion—albeit a framework somewhat lacking in specificity with regard to the precise nature of impairment.

This is the first study designed to test eyewitness recall and recognition memory under ecologically valid conditions involving physical exertion. Law-enforcement officers exerted themselves to the point of fatigue during a high-intensity assault exercise and then were exposed to a challenging interactive scenario. Following the scenario, participants were given three different memory tests. First, recall of briefing information encoded prior to the assault exercise was tested. In line with findings on the time-dependent nature of memory consolidation (McGaugh, 2000), our prediction was that physical exertion would disrupt the transfer of information into long-term storage and impair participants' ability to update previously encoded information. Second, we recorded participants' recall of two target individuals—one who was critical and one who was incidental to the scenario—to examine how intense physical activity affected episodic memory for a witnessed incident. Inconsistencies in the exercise-cognition literature, possibly attributable to methodological factors (Lambourne & Tomporowski, 2010; see also Etnier & Chang, 2009), make it difficult to generalize findings to more naturalistic witnessing contexts. However, time of test (during or immediately after exercise) does not appear to be systematically related to memory performance (see McMorris et al., 2011). Therefore, following arousal theories, we predicted that intense exertion immediately prior to encoding would negatively affect memory for incidental and critical targets.

Finally, participants completed an identification task for the critical target individual. Given that recognition is generally regarded as an automatic process (Jacoby, 1991), impaired performance by participants who physically exerted themselves might reflect a generalized attentional impairment due to reduced processing resources, whereas unimpaired identification performance might lend support to an attentional-narrowing account (Christianson, 1992).

Method

Participants

Fifty-two Canadian law-enforcement officers (42 males, 10 females; age range = 23–51 years, $M = 34.7$, $SD = 5.98$) affiliated with a metropolitan force were recruited for this study. Participants had served an average of 8 years as police officers. Participants were randomly allocated to either an exertion condition or a no-exertion (control) condition. There was no difference between conditions in the self-reported frequency of recreational physical exercise, $t(50) = -1.13$, $p = .27$, $d = 0.32$.

Materials

Briefings. All participants received a predeployment briefing containing information about three recent armed robberies in the area (e.g., the location of the crimes, perpetrators' modus operandi). After completing the main scenario, participants received two updates to the original briefing. Two types of update information were provided: additional information (details about a getaway car that had not been mentioned previously) and amended information (concerning the type of weapon used).

Lineup. All participants viewed a six-person lineup of color photographs, which included a critical target individual. The other five photographs were of males similar in appearance to the critical target. The lineup was presented in a simultaneous 3×2 array. Nontarget (i.e., filler) photographs were selected based on descriptions of the target (a match-to-description strategy; Clark & Tunnicliff, 2001). Lineup fairness was assessed by asking 65 mock witnesses to read a description of the target, view the lineup, and select the individual who best matched the description. Effective size estimates were calculated using Tredoux's (1998) E'. The effective size was 4.31 (95% confidence interval = [3.46, 5.69]), which suggests that the lineup included multiple plausible fillers.

Scenario location. A prefabricated building was decorated to represent an inhabited trailer—a context-rich, realistic environment. The front door opened into a furnished lounge area and a second door led to a bedroom. Four weapons (semiautomatic rifle, knife, shotgun, and handgun) were placed in the main lounge area. The rifle and knife were positioned within easy reach of the critical target individual whom participants encountered in the trailer. All weapons were clearly visible from the vantage point participants took during the scenario.

Procedure. Test sessions took place in a police training facility. Participants attended in pairs consisting of one member from the exertion condition and one from the no-exertion condition. After being fitted with Polar (Kempele, Finland) heart rate monitoring belts, participants were given the predeployment briefing. They were instructed to read the briefing carefully, because it provided information relevant to their operational duties. Then, while the control participant observed, the officer in the exertion condition, supervised by a qualified physical fitness instructor, began a high-intensity assault on a full-size punching bag. Participants in the exertion condition were free to hit the bag however they wanted (e.g., punch, kick, strike with palms or elbows) and were verbally encouraged to sustain the assault until visibly fatigued (breathless, struggling to continue).

Each participant in a pair was taken separately to the scenario phase in the trailer, which consisted of the same procedure for both groups. The participant in the exertion condition engaged in the scenario first. The distance between the gym and the trailer was 44.19 m. En route, the participant encountered the incidental target. This individual, who was not central to the scenario, made eye contact with the participant. Five seconds after the participant entered the trailer, the critical target (a middle-aged male wearing casual clothing) emerged from the bedroom area. Following a prepared script, he shouted at the officer to get out of his house. The scenario in the trailer lasted 15 s. When the scenario ended, the participant left the scene immediately, and the matched control participant then took part in the scenario. Participants in both conditions positioned themselves at the same vantage point in the trailer, which provided a clear, central view of both the inside of the trailer and the critical target during the scenario. After the scenario, each participant was provided with the two updates to the predeployment briefing.

After comparable short delays permitting recovery and refreshment in both conditions, participants completed the memory tasks individually. First, participants responded to 20 cued recall questions concerning the briefing information. Two questions targeted information that had been altered by the briefing updates. Second, participants were asked to report everything they could remember about the incidental target, the critical target, and the scenario. Then, participants were shown the lineup array, which included the critical target. Prior to this identification task, standard unbiased lineup instructions indicated that the critical target "may or may not be present in the lineup."

After the memory tasks, officers in the no-exertion group completed the exertion task to ensure that this group showed the same profile of physiological response during the bag assault as officers in the exertion condition. Blood lactate levels were recorded shortly after the exertion task in both conditions using an Arkray (Kyoto, Japan) LactatePro LT1710 (broadly, lactate measurements yield information about workload intensity and duration).

Results

Exertion manipulation check

Average heart rates were recorded in beats per min and analyzed to confirm that participants were physically taxed during both the bag assault and the trailer scenario (in which increased heart rate was a proxy for increased physical exertion). Average heart rates recorded for participants in the exertion condition during the bag assault were higher than those obtained from control participants observing the bag assault (exertion condition: M = 163.11, SD = 10.34; no-exertion condition: M = 104.31, SD = 16.84), $t(22) = -12.58$, $p < .001$, d = 5.36. Participants in the exertion condition also had higher heart rates during the scenario (M = 158.85, SD = 17.11) than did participants in the control condition (M = 105.44, SD = 19.69), $t(40) = -9.28$, $p < .001$, d = 2.93. As a manipulation check, control participants completed the bag assault task after the scenario. It is important to note that average heart rates for control participants on this task (M = 162.77, SD = 10.81) did not differ from those of participants in the exertion condition (M = 163.11, SD = 10.34), $t < 1$. Blood lactate scores did not differ significantly between the groups following the bag assault (exertion condition: M = 13.33, SD = 2.59; no-exertion condition: M = 14.16, SD = 3.81), $t < 1$. Heart-rate equipment failed for 10 participants in the control condition; however, excluding these participants from subsequent analyses did not alter the pattern of results. Participants spent an average of 56 s (SD = 6 s) on the bag assault.

Recall of briefing information

Participants in the exertion condition made fewer correct responses to cued recall questions concerning the original briefing than did participants in the no-exertion condition, $t(48) = 2.05$, $p < .05$, d = 0.59. Accuracy rates were calculated by dividing total correct items by total responses. There was a trend toward lower accuracy in the exertion condition, $t(48)$ = 1.85, p = .07, d = 0.53 (see Table 1). There was an association between condition and the accurate reporting of briefing updates, with 84% of participants in the no-exertion condition providing correct update information, compared with 52% of participants in the exertion condition, $\chi^2(1, N = 50) = 5.88$, $p <$ .05, $\varphi = -.34$. Of participants who provided correct update information, the majority (88%) provided additional information about the getaway car (only four responses included the amendment update about the weapon). Participants in the exertion condition also provided fewer correct update details (M = 2.14, SD = 0.77) than did control participants (M = 2.75, SD = 0.85), $t(32) = 2.13$, $p < .05$, d = 0.75.

Memory for targets

Participants in the exertion condition reported fewer correct details about the incidental target than did control participants, $t(48) = 2.47$, p = .02, d = 0.71 (Table 1). Accuracy of information provided about the incidental target was also lower in the exertion condition, $t(38) = 2.83$, $p < .001$, d = 0.92. Compared with control participants, participants in the exertion condition provided fewer correct details about the critical target, $t(50)$ = 2.15, $p < .05$, d = 0.61, and the accuracy of the information they provided was lower, $t(50) = 2.35$, $p < .05$, d = 0.66 (see Table 1). There was an association between condition and identification accuracy: Only 27% of participants in the exertion condition accurately identified the critical target from the lineup, but 54% of control participants made the correct identification, $\chi^2(1, N = 50) = 3.91$, $p < .05$, $\varphi = .27$. Forty-six percent of participants in the exertion condition and 38% of

Table 1. Recall of Briefing and Target Information by Condition

Information and performance measure	Exertion condition		No-exertion condition	
	M	*SD*	*M*	*SD*
Briefing (cued recall)				
Number correct	18.32	5.06	21.20	4.85
Accuracy rate	.83	.09	.88	.08
Incidental target (free recall)				
Number correct	2.52	2.63	4.36	2.64
Accuracy rate	.70	.30	.90	.12
Critical target (free recall)				
Number correct	6.77	2.47	8.19	2.29
Accuracy rate	.88	.13	.95	.08

control participants incorrectly identified a filler as the target, and 27% of participants in the exertion condition and 8% of control participants did not identify any lineup member as the critical target. There was no association between condition and whether or not participants reported the presence of a weapon (exertion condition = 81%; no-exertion condition = 77%). There was also no difference between groups with respect to the number of weapons reported (exertion condition: $M = 1.00$; no-exertion condition: $M = 0.92$), $t(50) < 1$.

Discussion

In the study reported here, law-enforcement officers who physically exerted themselves before witnessing an operationally realistic scenario displayed impaired recall and recognition performance. Such results are predicted, albeit in a nonspecific way, by models favoring an inverted-U effect of arousal on cognitive performance. However, our data support a more sophisticated explanation of the current findings based on compensatory control models (e.g., Hockey, 1997). Extending processing-resources accounts (e.g., Wickens, 1984, 2002), compensatory control models propose that when processing resources are compromised (e.g., because of arousal), individuals make strategic adjustments in the allocation of those limited resources in order to maintain high-priority task goals (Hockey, 1997). Such adjustments often produce decrements on secondary tasks or amplify trade-offs between tasks (Hockey, 1993; Hockey & Hamilton, 1983).

In the current study, processing demands for law-enforcement officers are likely to have included monitoring the immediate environment for risk factors (e.g., weapons) in addition to evaluating target individuals. Notably, although participants in the exertion condition provided significantly fewer details about the critical target individual and were significantly less accurate than participants in the control condition in identifying this target individual, there was no difference between conditions in the detection of weapons or in the number of weapons reported, which suggests that attentional resources may have been diverted to risk-assessment activities rather than the encoding of the critical target.

Poorer identification performance by participants in the exertion condition suggests limited attentional capacity at encoding as a consequence of competing processing goals. This finding supports the notion of a more generalized attentional impairment rather than attentional narrowing on the target. Although some research has identified interactions between exercise intensity, task difficulty, and resource allocation (e.g., Kamijo, Nishihira, Higashiura, & Kuroiwa, 2007), further research is necessary to examine processing goals, encoding priorities, and resource allocation during and shortly after exertion in context-rich environments. It should also be noted that the current study tested identification performance using a lineup in which the target was present. Future research should examine accuracy for lineups in which the target is absent in order to fully determine the effects of exertion on identification performance (see Wells & Penrod, 2011).

Our results also revealed an interesting effect of physical exertion on information encoded shortly before physical activity. Participants in the exertion condition showed poorer recall of the briefing encoded prior to the exertion phase (i.e., under the same conditions as control participants encoded the information). One potential explanation is that the process of memory consolidation for the briefing information was disrupted by the exertion phase. According to the theory of arousal-based competition (Mather & Sutherland, 2011), the priority level of information prior to the onset of arousal may produce differential effects on memory—that is, higher-priority information may be enhanced, but lower-priority information may be suppressed and may show retrograde impairment (Knight & Mather, 2009). In the present study, participants in the exertion condition showed retrograde impairment for the briefing information and were also less successful than those in the no-exertion condition at updating their preexisting knowledge of the operational context. Both of these processing deficits may be problematic, and indeed dangerous, in applied settings.

The delivery of justice may depend on the statements and identifications provided by witnesses who have experienced physical exertion, either in the course of their occupational duties or due to the nature of the crime perpetrated against them. Such witnesses may be required to justify or rationalize deficits or inconsistencies in their accounts (Beehr, Ivanitskaya, Glaser, Erofeev, & Canali, 2004). Thus, in addition to identifying important routes for future research, the current findings have an important value in forensic, legal, and other operational contexts by providing a novel and relevant demonstration of impaired eyewitness memory following physical exertion.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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