The Effect of Physical Exertion on Witness Memory

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 target 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.

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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 are not only cognitively demanding but also require bouts of intense physical activity (e.g. a chase on foot or physical encounter). Citizens who become victims of crime may also experience physical exertion during an assault or attempt to flee. Understanding how memory performs under witnessing conditions involving physical exertion is important. Firstly, detailed recall of perpetrators can protect the safety of occupational witnesses (and innocent bystanders) during live operations. Secondly, reliable statements and identifications provided by occupational witnesses, ordinary citizens and crime victims make a significant contribution to the delivery of justice – yet research has not directly examined the memory performance of exerted witnesses.

The broader literature on physiology and human performance presents a complex picture of the effects of exertion on cognition performance. While physical activity can have a facilitative effect on lower-level cognitive processing, such as reaction times, during and after exertion (see Audiffren, 2009, for 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 has a strong facilitative effect on speed of response for working memory tasks but a moderate detrimental impact on memory accuracy. McMorris and colleagues proposed that impaired accuracy on tasks during and following exercise may be due to increased 'neural noise' (a possible outcome of arousal-related increased concentrations of neurotransmitters). Other researchers have observed more generalized memory impairment as a result of high intensity physical arousal and 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 stressor leading to increased arousal levels as activity increases (e.g. Sanders, 1983). These models typically predict an inverted-U effect such that cognitive performance is poor under low intensity exercise but improves when an optimal level of arousal is reached. Beyond optimal arousal levels these models predict impaired cognitive performance. The current research did not aim to evaluate competing accounts of the effects of exertion on memory. However, this dominant account offers a general framework for interpreting witness recall performance during or shortly after exertion – albeit somewhat lacking in specificity with regard to the precise nature of impairment to complex processes such as memory.

Here we report the first study designed to test eyewitness recall and recognition performance under ecologically-valid conditions involving physical exertion. Law enforcement officers were exerted to fatigue during a high intensity assault exercise and then exposed to an interactive scenario followed by memory tests. Firstly, recall of briefing information encoded prior to exertion was examined. In line with recent work on the time dependent nature of memory consolidation (McGaugh, 2000), it was predicted that exertion would disrupt the transfer of information into longer term storage and impair participants' ability to update previously encoded information. Secondly, recall of incidental and critical target individuals was recorded to examine how intense physical activity would affect memory for a witnessed incident. Inconsistencies in the current literature are likely underpinned by methodological factors

(Lambourne & Tomporowski, 2010; see also Etnier & Chang, 2009) and make it difficult to generalize existing findings to more naturalistic witnessing contexts. However, in line with arousal theories and given little effect of timing for memory tasks (i.e. during or on the cessation of exercise; McMorris et al., 2011), it was 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 exerted participants might reflect a generalized attentional impairment due to reduced processing resources whereas unimpaired identification performance may lend support to an attentional narrowing account (Christianson, 1992).

Method

Participants. Fifty-two Canadian law enforcement officers (42 males) affiliated to a metropolitan force were recruited (23 to 51 years of age; M = 34.7, SD = 5.98). Participating officers had served an average of eight years as police officers and did not differ in self-reported rates of weekly physical exercise, $t(50) = -1.13$, $p = .27$, $d = .32$.

Materials

Pre-deployment briefing. A pre-deployment briefing was prepared containing information about three armed robberies that had taken place locally (e.g., location of crimes, modus operandi). Official 'updates' to the original briefing were also prepared, containing two types of information: *additional* information (further details about a getaway car) and *amendment* information (concerning the type of weapon used).

Lineup. A six-person simultaneous lineup was generated that included a clear color photograph of the target. Non-target (i.e. filler) photographs were selected using a match-to-description strategy (Clark & Tunnicliff, 2001). To assess lineup fairness, 65 mock witnesses read a description of the target, viewed the lineup and selected the individual who best matched the description. Effective size estimates were calculated using Tredoux's *E'* (Tredoux, 1998). The effective size was 4.31 (95% *CI* = 3.46 – 5.69) suggesting the lineup included multiple, plausible fillers.

Scenario location. A prefabricated building was decorated to represent an inhabited trailer (i.e. a context-rich realistic living environment). The front door opened into a furnished lounge area and a second door led through to a bedroom. Four weapons were placed in the main lounge area. A semi-automatic rifle and a knife were positioned centrally (easily accessible to the target). A single-barrel shotgun and a handgun were also present. All weapons were clearly visible from the participants' vantage point.

Procedure. Test sessions took place within a police training facility. Participants attended test sessions in pairs and were randomly allocated to either the Physical Exertion (PE) or Control condition. After being fitted with Polar Heart Rate monitoring belts, all participants were instructed to read the briefing carefully as it provided relevant information for their operational activities. Then, supervised by a qualified physical fitness instructor, the officer in the PE condition began a high intensity assault on a gym bag. Participants were free to select assault movements (i.e. punch, kick, palm, elbow strike) and were verbally encouraged to sustain the assault until visibly fatigued (i.e. breathless, struggling to continue). The exerted participant was then taken to the scenario phase of the study in the trailer. The distance between the gym and the trailer was 44.19 m. En route, the participant encountered the incidental target who made eyecontact with the participant. Five seconds after the participants entered the trailer, the critical target (a middle-aged male wearing casual clothing) emerged from the bedroom area. Following a pre-prepared script, he shouted at the officer to get out of his house. The scenario in the trailer lasted 15 s. Participants were then provided with the briefing updates. Afterwards, blood lactate was recorded using an Arkray LactatePro LT1710 (broadly, lactate measurements yield information about workload intensity and duration). At this point, participants were permitted recovery and refreshment. Participants in the Control condition observed the bag assault and proceeded through the scenario as per exerted participants. After comparable delays, all participants completed several memory tasks individually. The first recall task presented 20 cued recall questions relating to the briefing information. Two questions specifically targeted information that was altered by the briefing updates. Secondly, participants were asked to report everything they could remember about the incidental target. Finally, participants were instructed to report everything they could remember about the critical target and scenario. Prior to the identification task for the critical target, standard unbiased lineup instructions indicated that he may or may not be present in the lineup. After the memory tasks, officers in the Control group completed the exertion task as a manipulation check to determine that this group showed the same profile of physiological response during the assault as officers in the PE condition.

Results

Exertion manipulation check. Average heart rates (HRs), recorded in beats per minute, were analyzed to confirm that participants were physically exerted during both the bag assault and the interactive scenario (where increased HR is a proxy for increased physical exertion). Average HRs recorded during the bag assault for PE participants were higher than those obtained from

Control participants observing the bag assault (PE M = 163.11, SD = 10.34, Control M = 104.31, SD = 16.84), $t(22) = -12.58$, $p < .001$, $d = 5.36$. PE participants also exhibited higher HRs during the scenario (PE M = 158.85, SD = 17.11, Control 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. Importantly, average HRs for Control participants on this task did not differ from those obtained in the PE condition (PE M = 163.11, SD = 10.34, Control M = 162.77, SD = 10.81), $t < 1$. HR equipment failed for 10 participants in the Control condition; however, excluding these participants from subsequent analyses did not alter the pattern of results. Lactate scores did not differ between the groups following the bag assault task (PE M = 13.33, SD = 2.59; Control M = 14.16, SD = 3.81), $t < 1$. Participants spent an average of 56 seconds (SD = 6 s) on the bag assault.

Recall of briefing information. Participants in the PE condition reported fewer correct details in response to cued recall questions relating to the original briefing, $t(48) = 2.05$, p < .05, $d = .59$. Accuracy rates were calculated by dividing the total correct items by total responses. There was a trend towards lower accuracy in the PE condition, $t(48) = 1.85$ $p = .07$, $d = .53$ (see Table 1). There was an association between condition and the accurate reporting of updates to the original briefing with 84% of Control participants but only 52% of PE participants providing correct update information, $\chi^2(1, 50) = 5.88$, $p < .05$, $\varphi = -.34$. Of participants who correctly provided updated briefing information, the majority (88%) provided 'additional information' details (only four participants also updated their responses to reflect the 'amendment' information). PE participants also provided fewer correct update details (PE M = 2.14, SD = .77, Control M = 2.75, SD = .85), $t(32) = 2.13$, $p < .05$, $d = .75$.

Memory for targets. Participants in the PE condition reported fewer correct details about the incidental target than participants in the Control condition, $t(48) = 2.47$, $p = .02$, $d = .71$. Accuracy of information provided about the incidental target was also lower in the PE condition, $t(38) = 2.83$, $p < .001$, $d = .92$. Compared to Control participants, PE participants provided fewer correct details about the critical target ($t(50) = 2.15$, $p < .05$, $d = .61$), and the accuracy of the information provided was lower, $t(50) = 2.35$, $p < .05$, $d = .66$ (see Table 1). There was an association between condition and identification accuracy with only 27% of PE participants making an accurate identification decision while 54% of Control participants correctly identified the critical target, $\chi^2(1, 50) = 3.91$, $p < .05$, $\varphi = .27$. Filler identifications were made by 46% of PE participants and 38% of Control participants while 27% of PE participants and 8% of Control participants rejected the lineup (i.e. did not identify any lineup member as the critical target). There was no association between condition and whether or not the presence of a weapon(s) was reported (PE = 81%; Control = 77%). There was also no difference between groups with respect to the number of weapons reported (PE $M = 1.00$, Control $M = .92$), $t(50) < 1$.

Discussion

Witnesses who were physically exerted experienced significant memorial impairments affecting both recall and recognition performance. Such results are predicted, albeit in a non-specific 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 models propose that when processing resources are compromised (e.g. due to 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 (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 the evaluation of target individuals. Notably, although exerted participants provided significantly fewer details about both target individuals and were significantly less accurate than non-exerted participants, there was no difference between conditions in the detection of weapons or number of weapons reported suggesting that attentional resources may have been diverted to risk assessment activities rather than target encoding.

Poorer identification performance by exerted participants suggests reduced attentional capacity at encoding (consistent with competing processing goals) and, therefore supports 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 et al., 2007), further research is necessary to examine processing goals, encoding priorities and the allocation of resources during exertion and shortly thereafter, in context-rich environments.

Results also reveal an interesting effect of physical exertion on information encoded shortly before physical activity. PE participants showed poorer recall for details of the briefing encoded prior to the exertion phase (i.e., under the same conditions as Control participants). One potential explanation is that the process of memory consolidation for the briefing information was disrupted by the exertion phase. According to arousal based competition theory (ABC; Mather & Sutherland, 2011) the priority level of information prior to the onset of arousal may produce differential effects on memory – specifically, higher priority information will be enhanced but lower priority information may be suppressed and show retrograde impairment (Knight & Mather, 2009). In the current study, PE participants showed this retrograde impairment for the briefing information and were also less successful at updating their pre-existing knowledge of the operational context. Both of these processing deficits may be problematic, and indeed dangerous, in applied settings.

The delivery of justice may rely on the statements and identifications provided by witnesses who experience physical exertion either in the course of their occupational duty when responding to incidents or due the nature of the crime being perpetrated against them. Such witnesses may be required to justify or rationalize deficits or inconsistencies in their evidentiary accounts (Beehr et al., 2004). Thus, in addition to identifying important routes for future research, the current findings have important value in forensic, legal and other operational contexts by providing a novel and relevant demonstration of impaired eyewitness memory following physical exertion.

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Table 1. Mean Briefing and Target Information Recalled by Condition

Details		PE Condition		Control Condition	
		M	SD	M	SD
Briefing (Cued Recall)	Correct	18.32	5.06	21.20	4.85
	Accuracy Rate	0.83	0.09	0.88	0.08
Incidental Target (Free Recall)	Correct	2.52	2.63	4.36	2.64
	Accuracy Rate	0.70	0.30	0.90	0.12
Critical Target (Free Recall)	Correct	6.77	2.47	8.19	2.29
	Accuracy Rate	0.88	0.13	0.95	0.08