Exhibit 26
(Dennis Deposition)

Transcript of the Testimony of **Andrew Dennis, DO**

Date: October 26, 2016

Case: The Estate of TONY ROBINSON v. THE CITY OF MADISON, WISCONSIN

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IN THE DISTRICT COURT OF THE UNITED STATES
FOR THE NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

The Estate of TONY ROBINSON, JR., ex. rel. personal representative ANDREA IRWIN,	)	
Plaintiff,	)	
-vs-	)	No. 3:15-CV-502
The CITY OF MADISON, WISCONSIN, and MADISON POLICE OFFICER MATTHEW KENNY,	)	
Defendants.	)	

Deposition of ANDREW DENNIS, D.O., taken before ROBBIN M. OCHENKOWSKI, C.S.R., and Notary Public, taken pursuant to the Federal Rules of Civil Procedure for the United States District Courts pertaining to the taking of depositions, at 311 North Aberdeen Street, Third Floor, Chicago, Illinois, commencing at 1:15 P.M. on the 26th day of October, A.D., 2016.

There were present at the taking of this deposition the following counsel:

PRESENT:

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The City of Madison, Wisconsin.

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DEPOSITION OF
ANDREW DENNIS, D.O.

October 26, 2017

EXHIBITS

(Witness first duly sworn.)

ANDREW DENNIS, D.O.,

called as a witness herein, having been first duly sworn, was examined upon oral interrogatories and testified as follows:

EXAMINATION

BY MR. OWENS:

Q Good afternoon, Dr. Dennis.

Is doctor the right term?

A Yes.

Q Can you please state and spell your name for the record?

A It's Andrew, A-n-d-r-e-w, Dennis, D-e-n-n-i-s.

Q And I know you've testified in court a number of times, but have you given a deposition before?

A I have.

Q How many times?

A Prior to ten.

Q Have you given any depositions in the last four years?

A Yes.

Q And can you give me a list of all of the depositions that you've given testimony in in the last four years?

A I gave one last week.

There should be a list included on the report as testimony.

Q Yes. So this includes all of your testimony, in court --

A Yes.

Q -- and depositions?

A Yes.

Q There are no new additions?

A There's one new addition that was last week, yes.

Q Do you recall the names of the parties in the suit?

A Sett --

Hang on. I can tell you. Salem, S-a-l-e-m v. Sepia, S-e-p-i-a.

Q And what kind of a case is that?

A That was a motor vehicle crash. They claimed, they're stating, that the hernia was caused by a motor vehicle crash.

Q And was your testimony in that case offered to rebut that claim?

A Yes, as a surgeon.

Q Were you the treating surgeon, or were you

retained in that case?

A I was retained.

Q Who were you retained by?

A A company called INSPE, I-N-S-P-E.

Q Were they related to the owner of the car in some way?

A No.

It's a company that finds expert physicians for specific cases for attorneys.

Q So they sort of -- attorneys go through them to say we need an attorney --

A Yes.

Q -- for this specific purpose?

A They need a surgeon. INSPE will say, we have X, Y, Z surgeons.

Q Do you use INSPE for all of your expert work, or how does that work?

A No. It's word of mouth. Everything that comes to me is either word of mouth or through INSPE.

Q How did this case come to you?

A This case here?

Q Yes.

A Word of mouth.

Q So when you say word of mouth, you mean you just

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got a call from the defendant's attorneys one day and they talked to you about the case?
A Correct.
Q So I know you've been deposed a number of times, but just for the record and so we're on the same page, I'll go over some of the ground rules.
You know this is just like testimony in court and under oath and that in the same way?
A I do.
Q And because there's a court reporter here but no video or jury or trier of fact, it's important that you give audible answers.
A Yes.
Q And you know, if you ever need a break, obviously, we'll take one, but I would ask that you wait until I finish asking a question before answering, okay?
A Sure.
Q And, of course, I think that probably maybe the most important thing is that you are entitled to questions you can understand and that should be clear. Sometimes I'll ask garbled or unclear questions that Tim may object. Even if he doesn't, you as a witness are entitled to that. So if there's ever something that

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you don't think I'm clear about, please let me know, okay?
A Okay.
Q The flipside is, if you do answer a question I ask, I'll assume that you understood it, okay?
A Okay.
Q Now, you've prepared an expert report in this matter, is that right?
A Correct.
Q Can we mark this as Exhibit --
MR. OWENS: We're on 227, right, Amanda?
MS. KAISER: I'm not even sure.
Yes, that's right. Or maybe 226.
MR. OWENS: No. 226 was the close-ups.
MS. KAISER: Okay.
BY MR. OWENS:
Q And, Dr. Dennis, this is a copy of your report in this case and your 26(a) Disclosures, is that right?
(Exhibit 227 marked.)
A Correct.
Q And does that report include all of the opinions you have to offer in this case?
A If it's complete, it does.
Yes, it does.

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Q Do you have any new opinions since authoring this report that you intend to offer in this suit?
A No.
Q Have you reviewed any additional documents since completing your report?
A No.
Q Have you reviewed any other evidence at all since completing your report?
A No.
Q Now, I just wanted to get some clarification about the documents that you did review in preparing your report.
So on page -- it's going from on the bottom of page 2. You've got the complaint. You've got, it says, Wisconsin Department of Justice DCI 15-1188/40.
That's the interview of Matt Kenny?
A Correct.
Q The deposition of Sam Marso?
A Correct.
Q The deposition and then the medical records.
I just want to be clear about the medical records you reviewed. So we can go ahead and --
MR. OWENS: Amanda, I'm marking the two exhibits here. The first set of medical records that we received

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will be Exhibit 228, and then the second set of records we received yesterday will be 229.
Okay?
MS. KAISER: Okay.
(Exhibit 228 and Exhibit 229 marked.)
BY MR. OWENS:
Q Dr. Dennis, I'll represent to you this is -- these are the documents that counsel informed us that you obtained and reviewed in advance of your deposition today.
Does that look right?
A Yes.
Q Are there any other additional medical documents that you reviewed?
A No.
Q Do they sort of come in sort of substantially a similar format?
A Electronic, yes.
Q But it's two PDF's, one --
A Two PDF's, both electronic, yes.
Q Now, there is -- as you know and because you've done this before, I just want to be clear about what your testimony isn't. So this is not sort of a list of

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questions to argue with you. I just want to make sure of the things that you're not opining about or testifying about in this case.

And the first thing is, you haven't seen a video of this shooting, have you?

A I have not.

Q I think you said this a minute ago. You don't have any new opinions to offer today?

A I do not.

Q Except those that are provided in your report?

A That's correct.

Q And you haven't looked at any CT scans, is that right?

A No.

Q You haven't looked at any X-rays of Officer Kenny, is that right?

A Correct.

Q You haven't seen any MRI's or magnetic resonance imaging reports, correct?

A I have not.

Q And you don't have any opinions about the actual substance of any of the experts' reports that you reviewed in this case, is that right?

A Can you clarify that?

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Q Sure. So in your -- on page 2 you reviewed the deposition of Sam Marso, right?

A Yes.

Q And you're not here to offer any opinions about whether he got things right or wrong about the reconstruction or anything like that?

A Correct.

Q And you aren't going to offer any opinions about Dr. Arden's report, is that right?

A Correct.

Q The same thing with Mr. Denny -- Dennis Waller, correct, right?

A Right.

Q Now, in your report you mentioned that you reviewed five articles in particular on page 3 of your report, is that right?

A Correct.

Q Now, how did you go about selecting these articles?

A Some were taken from references from the Force Science Institute. Others were searched on PubMed. I collected an extensive bibliography and selected the ones that I felt were most relevant.

Q And that bibliography is not part of your report, is it?

A No.

Q Do you have any record of that?

A I don't. I mean, it was just an extensive search pulling down the search titles and then tracking the -- looking at the abstracts and deciding this was relevant or this was not relevant to the case.

Q What were you looking for when you were trying to determine what was relevant and what was not relevant?

A I was specifically looking at peer-reviewed publications specific to concussive head injury and memory as well as -- the other word escapes me -- as well as excitation or exertion and memory and stress.

Q So you were looking for articles about the relationship between stress and memory, is that one of the things?

A One of them.

Q And then you were also looking for, I think you said, excitation and memory?

A Yes, arousal or excitation associated with exertion, yes.

Q And you're talking about like physical arousal then?

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A Correct. Correct.

Q And we'll discuss all this more in detail later.

And before doing your search on PubMed, were you familiar with any of these articles specifically?

A Several of them, yes.

Q Which ones?

A I was familiar with the Hope L. Lewinski, I was familiar with Morgan, actually, both Hope articles and one of the Morgan articles as well as the Lynch article.

Q So which of the Morgan articles?

A Misinformation can influence memory.

Q So the only new article that you found that you hadn't --

A Was The Operational Witness by Morgan.

I'm sorry. No. By -- Perspective: I believe what I remember.

Q Perspective: I believe what I remember, but it may not be true?

A Correct.

Q So I know you've got an extensive background.

How would you describe your title?

A My primary job?

Q Yes.

A Division Chair of Pre-Hospital and Emergency

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Trauma Services at Cook County Hospital.
Q Is that also called Stroger Hospital?
A It is.
Q And what are your duties in that?
A Trauma and burn surgeon.
Q Are you sort of active, do you perform active, are you actively in surgery and treating patients now?
A Everyday.
Q And when you say -- it's fair to say your specialty is in trauma and burn, is that right?
A Trauma, burn and critical care.
Q What do you mean by that?
A ICU care.
My board certification is general surgery, critical care, so ICU management, and my fellowships are trauma surgery and burn surgery. So I'm an injury doctor.
Q What percentage of your income comes from your primary job at Cook County Hospital?
A A hundred percent of my income comes from that.
Q So you don't make any income from --
A I have supplemental income, but my salary as a trauma surgeon at County Hospital is my primary source of income. Everything else is supplemental.

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Q So you have a number of sources of supplemental income, correct?
A Yes.
Q What are those?
A I live in Chicago. I have to.
Q Right.
A I am -- I'm an executive medical advisor for NBC for Dick Wolf Productions so Chicago Med, Chicago Fire, Chicago P.D. and Chicago Justice.
Q So you do consulting for those T.V. shows?
A Correct.
Q What else?
A I work for the sheriff's office, but that salary is actually my county trauma salary, and it's just an MOU between the sheriff's office and the hospital so there's no additional supplemental income as a police officer.
Q And in the sheriff's office, are you still a member of the SWAT team? Is that right?
A I am.
Q And how often are you an active SWAT team member?
A At least two, three days a week depending on what we're doing. I mean, I'm -- it's every day

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depending what the needs of the team are.
Q Got it.
I guess I'm just trying to understand the relationship between if you're at the hospital and then how does it work when you are also on the SWAT team, what determines what you're doing or how you're doing it in a given day?
A If I'm on call at the hospital and we have an operation for the police department, I either have to get coverage or I'm not available. I supervise several paramedics on the team so they can function independently of me as well as my residents on the team.
Q Got it.
What's your role on the SWAT team?
A My role at the sheriff's office is medical director of the sheriff's office as well as the state police, and it's administrative, it's training, and it's operational. So I supervise the paramedics, I make sure that their training is squared away and up-to-date. If we go out on a search warrant or a barricaded subject, I will 95 percent of the time know, and I will be indistinguishable from any other police officer on the team other than being a surgeon. My primary responsibility is the medical response of the team. I'm

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not the one kicking in the door, the first one in or the last one in, but, nonetheless, I'm still an active part of the team.
Q Okay. How long have you been a sworn police officer?
A In Illinois since 2002.
Q When is the first time you were a sworn police officer in any state?
A In Massachusetts. Yes, Massachusetts.
Q You've got -- Your c.v. is attached to your report here which we've marked as an exhibit.
Are there any updates or new editions other than the testimony you described in your c.v. or is it current?
A It's current.
Q So some of your supplemental income comes from NBC, some of your supplemental income comes from your work?
A Occasional expert testimony.
Q And what percentage of that, of your income, does that comprise?
A Less than five percent.
Q And in this case have you charged your standard rate?

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A I have.
Q Do you have a standard rate?
A Yes.
Q What is that?
A $750 per hour.
Q Have you ever been retained in a criminal case, or do you do mostly civil work?
A No. I'm frequently involved in criminal cases as a treating physician.
Q Got it.
Now, in situations where you're not a treating physician, are you --
Actually, sorry. Strike that.
Putting aside cases of where you're a treating physician, your role is usually more limited to testify about what you did in a particular surgery or treatment plan, right?
A Correct.
Q Putting those to the side, when you give expert testimony when you've been retained independently, what's your criteria for determining whether or not you're going to take a case or not?
A If I feel that the case, that I can offer an expert opinion and my training and expertise is within

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the scope of that case, then I will offer to take the case.
Q How would you sort of describe the areas of expertise that you can offer expert opinion in?
A Anything to do with injury, certain things within law enforcement, the scope and breath of topics such as this, memory and performance with regards to injury.
Q Now, you said anything with respect to injury.
Is that sort of all injuries?
A Yes. I mean, that's what my medical expertise is injury. I'm an injury surgeon.
Q Now, is there any differentiation between different types of injuries like brain injuries are treated by different surgeons or doctors than sort of maybe, you know, bruises or cuts?
A So if you are mildly injured, then, typically, an emergency doctor may be able to handle it. If your injury has multisystem parts to it, then that escalates it to a trauma center, and that would fall under my purview.
But the range of injuries I take care of are from scratches and bumps to multiple gunshot wounds, high-mechanistic injuries from car crashes, long falls,

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struck by vehicles, blows to the head, assault and battery.
Q Got it.
But I guess I'm wondering, do you routinely treat or see patients for brain injuries or is that something that --
A Everyday.
Q But you're not a neuroscientist?
A I'm not a neurosurgeon. I'm not a neurologist.
Q Now, you said that could testify in the field of certain topics related to law enforcement, right?
A Sure.
Q What are those topics?
A Having never actually thought about this specifically before, certain use-of-force cases, electronic control devices, specifically the Taser, which is where a good portion of my research has been done, medical management in the field by police officers, things like that.
Q And you're not, just to be clear, offering any opinions about Taser or testimony here about electronic control devices at all, correct?
A Correct.
Q Have you reviewed Expert John Peters' report in

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this case?
A Was it on my list?
No.
Q Do you know who Mr. Peters is?
A No.
Q And you don't have any use-of-force opinions in this case?
A I do not.
Q Now, I'm right that you don't have any formal training in psychology or psychiatry, correct?
A Correct.
Q And you have never done any experimental psychology work in memory or perception, have you?
A Actually, yes. So I have participated in several projects that have not been published with regards to performance, memory, cognition and perception.
Q Sorry. I should have asked that question a little bit better.
Have you received any training in memory and perception?
A Yes. I went to the certification course at the Force Science Institute.
Q And that was earlier this year -- or last year?
A Last year, a year and a half ago, two years.

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Q So other than going through the Force Science certification, have you received any training in memory and perception at a university?

A Cognition and post-concussive syndrome is something I do on a regular basis, and it was part of my trauma fellowship so I see those patients in follow-up or I see them initially and in follow-up. So dealing with concussive injuries and the cognitive pieces to their convalescence, I am trained in at the residency level and the fellowship level.

Q Right.

But you haven't done any sense of training at a university in like sort of the field or -- the field of memory and perception specifically, have you?

A I mean, are you asking am I an active researcher? Yes. Do my areas of interest involve memory and perception? Yes, they do. Do I have a Ph.D. or a Master's in that? No, I don't.

Q Right.

I mean, you're familiar with Elizabeth Loftus, right? Are you familiar with --

A No.

Q So the opinions you've offered in your report today, are they consistent with the certification you

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received from Force Science?

A Part of the education I received at Force Science definitely relates to this.

Q And my question was a little bit different, which is do you think that everything that you were taught in the Force Science training is consistent with all of the opinions you've expressed here?

MR. JOHNSON: Well, objection to form.

THE WITNESS: I think there are a lot of similarities in the exposure I had in Force Science, but my experience is not limited to my experience in Force Science.

BY MR. OWENS:

Q Right.

And I guess I'm wondering whether or not there's something that you saw in Force Science that they told you this isn't how one aspect of memory works, and then in your report you provided in this case you've departed from that a little bit or pushed back or disagreed with them in any way?

A No, I haven't.

Q You've never been a law enforcement officer in the State of Wisconsin, correct?

A Correct.

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Q Can you explain to me your role with the Illinois State Police?

A Again, it's -- I just took this position, and I was asked to become the co-medical director for the Illinois State Police. That position really is evolving so it's a lot of training and making sure the SWAT team medics are squared away at this point in time, it's being a resource for the state troopers, for themselves and their families when they have medical issues that arise.

Q So you're -- So you're treating the medic -- excuse me -- the law enforcement officers?

A I'm a liaison from the state police to the physicians all around the state that are caring for troopers and their families when they ask for the assistance, someone to translate, and the majority of it is unrelated to law enforcement or their primary duties.

Q In any of the cases in which you provided non-treating expert testimony, have you ever testified against police officers?

A No.

Q Have you ever given any opinions opposed to law enforcement?

A Yes.

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Q In what cases?

A So I've been -- none of these cases that actually went to deposition, but I've been consulted on several. I've given positions that have not been favorable to law enforcement, and they've declined to have me take the case.

Q Do you have a list of any of those cases?

A I don't because those are usually phone conversations.

Q So people call you, they throw out a scenario, and you say, I think that your guy is in the wrong, and then you don't hear back?

A Potentially, yes.

Q Now, I wanted to talk or get a little bit more background about the law enforcement medicine fellowship program and the team that you put together.

Can you describe that work for me?

A You're talking about the law enforcement medical asset team at Cook County?

Q Yes.

A So that took off for a while, and then the attorneys got involved --

Q Yes.

A -- and the liabilities -- we actually tabled

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that team right now because the liabilities associated with the team are still being worked out.

So instead what we have is myself and the residents as part of their training program have the opportunity to participate with the state police, with the Cook County Sheriff's Office, and we'll put them through basic SWAT school, and they will learn the nuances of law enforcement medicine, specifically tactical medicine in the field, but the team, itself, is actually tabled as an institute.

Q And just going through your extensive background and experience, and you can correct me if I'm wrong, you don't have any articles specifically that are in your current c.v. about memory and perception, correct?

A Correct.

Q And you don't have any about the effect of, you know, traumatic head injury on retrograde or antegrade memory, correct?

A No, I don't.

Q So sticking with the topic of your supplemental income, how much supplemental income do you derive from your LLC countermeasures, or do you refer to it as the DBA, which is --

A Medical tactics.

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Q -- medical tactics?

Is that a better way --

A Depending on the year, anywhere between 20 percent, 20 to 30 percent, but within that LLC I roll up all of my expert testimony and all of the courses that the company teaches. It all comes under the countermeasures for tax purposes.

Q So does the testimony that you're giving here have -- fall under that or does it fall under --

A It falls under the LLC. Any -- Any income that might come from that falls from that number for tax purposes.

Q So today you're giving testimony obviously as yourself but also under the guise of the medical tactics?

A Or countermeasures.

Q Or countermeasures?

A Yes, yes.

Q How much time in a given month do you spend working on countermeasures or related trainings or events?

A Specifically testimony or specifically the educational component?

Q No, just generally. So I know you're extremely busy, but how actively involved are you in countermeasures on a regular basis?

A Probably five to six hours a month on average.

Q Then --

A The company for the mostpart has been moved to an online platform for education so we're no longer -- I'm no longer going around the country teaching these courses. I have a couple of instructors that do that still but not me.

What I've done is built the Illinois platform so it becomes passive income, that was the intent.

Q So you built it up, and then now --

A Well, the intention was to actually take the course, the medical tactics course, and make it more amendable to schools and law enforcement agencies and anyone that wants to take it so that you didn't have to take it after work so you could do the coursework online on your own time.

Q Sure.

A So that's -- yes.

Q Now, I know I have your case testimony history here, and I just want to sort of run through this --

A You're assuming I remember most of this.

Q -- somewhat quickly.

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That's all right. It's not a memory test, which is an ironic thing to say, but the --

Let's -- Sorry.

This is Appendix A from your report. Wilder against Wexler, what's that case about?

A You asked me the one I do remember.

That case just settled. That was a case involving an inmate in the state penitentiary suing Wexler, who was the healthcare provider contracted to the state, regarding his hernia that he said he had that was not cared for.

Q What was your testimony in that case?

A My testimony is that he didn't require an operation and that the management that the physicians at Wexler provided was appropriate.

Q In that case you provided testimony that the standard of care provided by the Illinois Department of Corrections was adequate, is that fair to say?

A Correct.

Q What was the case Tapia against S-k-a-r-u-p-i-n-s-k-i, Skarupinski?

A Yes.

I actually don't remember the details of the case.

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Q And you were retained by the City of Chicago, correct?
A Correct.
Q Do you have a copy of your report from that case?
A I don't think I had a report for that case. You know, actually, I don't recall.
Q And the reason I was assuming that was because it says here Defense for the City of Chicago Report.
A Then, yes, there's a report on my computer somewhere.
Q Do you recall what Palmar against the Chicago Housing Authority was about that was one of your treating cases?
A Correct. I believe this was a fall and a burn.
Q So in this case you were not specifically retained, you just testified about the work you did on the burn?
A I took care of the patient, yeah.
Q Do you remember what Belinda West against Thomas Jefferson University Hospital was about?
A I don't remember the details of the case at all so not enough to give you any --
Q But you were testifying on behalf of the

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hospital that the -- it sounds like a patient who died didn't -- that the hospital shouldn't be liable for that death, is that right?
A Right. Separate from the physician. I was not defending the physician, as I recall.
Q Do you recall what your -- sort of the nature of your testimony was in bringing it against Cook County?
A Actually, I don't.
I think I was being sued here.
Q So I was wondering because it says, you know --
A So I was dismissed eventually, but this was a case where I was sued.
Q So you were a defendant in this suit?
A Initially, yes.
Then the hospital system was the defendant, and I was -- I was excused from the case.
Q Have you been sued any other times in your career related to your --
A I've been sued twice in my career.
Q Related to your experience as a doctor?
A Correct.
Q And this is one of them?
A Yes.
Q What was the other time?

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A The other one is actually still open. It was an obstetric case where I was called in as the rescue surgeon on a maternal death. They're suing Cook County, and somehow my name got wrapped up in the case because I was the one who came and tried to save her life. She still died.
Q Do you know how long ago that happened?
A It happened last -- I think within the last two years.
Q Now, have you ever given testimony in your role as a police officer?
A Specifically, you mean as an arresting officer?
Q As a police officer in any way whatsoever. We can start broad and go from there.
A I try to stay -- My role with law enforcement is mostly exempt rank positions so I do very little paper, so I can't tell you even in the last five to ten years that I've had to be in court as a police officer.
Q Okay. What about before that?
A Traffic tickets, I mean, traffic arrests, things like that.
Q Have you ever been sued as related to your actions as a police officer?
A No.

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Q Have you ever given testimony in a police shooting case, an officer involved shooting case?
A Yes.
Q When was that?
A I haven't -- I actually haven't had to give testimony yet. I've given a report on it. Actually, I haven't even -- I take that back. I haven't been asked for a report yet. I just had consultations from the City of Chicago on a case.
Q And you've been retained?
A I have been retained as just for phone consultation opinions, but the case -- I don't even know if the case was settled or not. So I haven't heard from them in about nine months.
Q Do you know the name of either the officer involved or the individual who was shot?
A There were multiple officers involved. There was a case treated at Mount Sinai. The gentleman was being robbed. He came out of the storefront chasing the offenders. The cops pulled up. The offenders dropped the gun. He picked up the gun, was mistaken as the offender and shot by the police.
Q Oh, brother.
A Despite being asked to put down the gun. It

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ended up not being life-threatening.
Q The injuries?
A Yes.
Q Okay. So other than sort of being retained in a consultation, have you ever given deposition testimony in a police shooting case before?
A Not shooting.
Q Have you ever been -- given courtroom testimony in a police shooting case before?
A Just as a treating physician.
Q And have you ever been qualified as an expert to testify about memory and recall?
A No.
Q Have you ever been qualified as an expert to testify about concussions?
A Yes.
Q How many times?
A Once or twice as a treating physician related to multiple other injuries in addition to that.
Q Have you ever given testimony in court about opining about a concussion or the effects of a concussion of somebody that you didn't actually treat yourself?
A No.

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Q So is it fair to say you do less sort of public media work?
I know in looking there are over your -- I'm trying to get a general sense of the arc of things here because there's so many things on your c.v. to possibly talk about, and I want to stop boring you and start talking about some other stuff, but the -- am I right that you're doing less sort of like affirmative media work discussing the role that you're in as a police officer and a surgeon, or is that stuff still ongoing?
A Occasionally, I get asked about it. There's been a couple of articles of late. It always comes up with someone when I get interviewed, but, you know, it comes up once or twice a year.
Q And I know a number of those articles have focused on your perspective as a law enforcement officer and sort of seeing, thinking about traumas.
Is that a topic you've been asked about or are still asked about?
A Yes.
Q And do you think that you perceive, you know, trauma and injuries related to law enforcement action differently due to the fact that you are also a law enforcement officer?

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A I think that being a law enforcement officer and having a pre-hospital background as a paramedic and ENT as well as a trauma surgeon allows me to understand environments and how they relate to individuals and circumstances before they come to the hospital as well as when I have the opportunity to discharge them from the hospital to have an idea of where they're going back to, and that's sort of where you need the perspective to have in a trauma center like mine which is highly violence-driven.
Q Do you think that your work in being a law enforcement officer influences the way in which you practice medicine?
A No. I take care of patients, and I've been in circumstances many times before where I've had the officer in one bed and the offender in the next, and the office was shot and so was the offender, and everybody gets taken care of equally prioritized based on triage and need for -- what needs to be done.
Q I didn't mean to imply anything else.
Do you think that your work as a surgeon and a trauma surgeon affects the way in which you are an active police officer sort of on the street as you perceive the events as they take place?

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A Certainly, I do.
I think that, you know, my job -- a good portion of my job would be equatable to a flight surgeon assigned to an air force quadrant, which means that my job is to make sure the officers are mission ready, that the pilots are mission ready, and the same thing with the police officers. So I have to understand their job from the details and nuances to say whether someone should be doing it, shouldn't be doing it, should be kept out of work, should not be kept out of work and to make sure that the, you know, the ultimate of what they're supposed to be doing on the street, that they're safe, the public is safe. So all those things play into that, and that gives me a very different perspective, I think, than other doctors.
Q So the work that you do or have done with countermeasures, I know a portion of it focuses on having officers not respond to their emotions or what they think is going to happen in situations, is that a fair summary?
You're kind of smirking.
A Yes, actually, exactly.
That either came from my website or you read the book already.

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Q I got it right here.
And I, you know, you haven't mentioned your book in your report today, and I just want to make sure this is clear for you, and you know, I think Tim and Amanda, too, that my questions today aren't intended to expand or elicit any new opinions from you but merely just sort of explore the bases for them.
And it seems like you're offering testimony here today in this case about memory and officers' responses to high-stress environments, and you also have written a book and have a training company that also discusses overlapping --
A Correct, performance and perception and how they interrelate.
Q And the -- am I right that part of the work that you've done with countermeasures is -- involves officers being sort of instructed or trained in how to -- in how their memories can fail them in certain situations?
A Yes.
Q And I think one example that you used in the past involves an officer who thought he had been shot, right?
A He was shot.
Q Who thought he was dying?

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A Oh, he was dying.
Q Dying and bleeding out and all that stuff, right?
A Correct.
Q Can you just describe -- I've seen snippets of that online and in your book, but can you sort of describe to me the basic situation of that example and why you used it as a teaching tool?
A It was a Chicago Police Officer.
Remember, these things correlate both to physicians and doctors -- and police officers and anyone that works in a stressful environment, and that was the intent of it.
It was a police officer who was shot. The paramedics called and said, we have a police officer -- Chicago Police Officer shot in the chest, he's unstable, his blood pressure is low, we think -- we're coming to you, our ATA five minutes or something like that.
He comes in. He was pale, he was sweaty, he looked like he was in shock, he looked like he was sick as we would call it. And so we went through the A, B, C's, evaluated him, took all his clothes off, ended up not finding an injury, gave him some IV fluids.
He perked up, came around, his blood pressure

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picked up, his heart rate came down, and he was no longer looking like he was in shock, picked up his vest off the ground, found that he had in fact been shot in the chest, the bullet had struck a book that was in his outer pocket, but, psychologically, he felt that -- he was basically in psychogenic shock, he felt that, if I got shot in the chest, I was going to die. That's what he had talked himself into.
Q And am I right that part of the thought there that's sort of his physical response was a manifestation to what he believed was going to happen based upon what had happened to him?
A Correct.
Q And --
A Based on his frame of reference.
Q Got it.
Can you explain a little bit more what you mean by that?
A I think the philosophy is that one's fear of reference influences his or her perception, and perception can influence one's mindset or one's fear, which can influence one's mindset, which can have a dramatic impact on their physiology, their heart rate, their blood pressure and the way they breathe, and all

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those things culminate in actions and reactions in what we call overall reaction, which is defined as decisions and reactions.
So if your frame of reference is flawed, your perception can in fact be inaccurate and your fear can be misleading, mindset can be compromised, physiology can be elevated or incorrect, out of portion to the events, and your overall decisions and reactions can be flawed.
The reverse is true as well. If your frame of reference is correct, your perception is correct, your fear is in check, your mindset is strong, your physiology is in check, and your overall decisions and your actions are appropriate.
Q Got it.
And the -- I know this is in your book, and maybe we don't need to go into it.
A You're the second person that read my book so that's cool.
Q I was wondering if you got an e-mail when I downloaded it.
A No.
Q You know, there's a statement that you made, you know, that the studies indicate that, you know, emotions

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frequently dominate tactics on decisions, therefore, inactions therefore suffer, resulting in terrible losses.

Do you recall that?

A I do.

And that relates specifically to medical management because that is typically the most emotional thing for anyone, teachers, cops. If you're not trained to do it, it can be emotionally very challenging to overcome those hurdles and objectively look at things. In fact, that's common with doctors.

Q Got it.

And does this statement here, I just want to be clear about the bases or the scope of it, also apply to use-of-force tactics, you know, if officers' emotions dominate in what they perceive can happen, then you can get more terrible outcomes as a result?

A I think that's a pretty broad-stroked statement to make. I would not necessarily agree with that.

I would say that there have been studies that have shown that anticipated responses may not be what actually happened. So there have been studies that looked at officers placed under stress when they were asked to recount the circumstance as operational

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witnesses that they perceived a weapon to be out when in fact it was a cell phone or the weapon was not in fact out.

Q Right.

So -- I'm sorry. Was your answer done? I didn't mean to interrupt.

A Correct.

Q So there you're sort of specifically referring to the Hope study from 2015 in which a number of the officers who were in the operational setting thought that -- say that the guy, the suspect, as the study held, had a weapon when in fact he did not?

A Well, he had a weapon. It just wasn't pointed. In that study there was a weapon.

Q He never removed -- He thought he was pointing a weapon at him, and he wasn't, correct?

A Right.

Q Now --

A But those were not physical encounters, remember? They were perceived at a distance.

Q Sure. And that's my next question. So I just wanted to make sure I was understanding what you were referring to when you said you were referring to studies.

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So I know you're referring to the Hope 2015 study, and then am I right by saying, clarifying for something about physical encounters, you are sort of amping up to refer to the Hope 2013 study?

A I'm trying to stay within the realm of what the report defines so yes.

Q Sure. I'm just trying to understand, when you say there are studies that say X, Y, Z, is that what you're referring to?

A In this case, yes. One of them, yes.

Q What are the other ones? Sorry. What do you mean by one of them?

A I mean, I listed several studies here so the Hope studies were -- in that case that's the study I was referring to.

Q So your opinions here are based upon the studies that you've cited in your report?

A And my experiences.

Q Have you ever met Officer Matt Kenny?

A I have not.

Q Have you -- Do you know him personally at all?

A I do not.

Q Have you ever evaluated him medically?

A I have not.

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Q Have you ever spoken personally with any of the doctors who treated him?

A I have not.

Q So you didn't have any conversations with Dr. Rickman, Ray, Enz or Shah?

A No.

Q So I just want to start by asking for just a couple clarifications, your methodology, to how you put together your expert report in this case.

Do you have a standard approach or methodology that you adopt when preparing an expert report?

A Do I have a standard one? No.

I typically formulate an outline in my head as to -- for what I'm being asked to evaluate. It's just like a differential diagnosis when you're taking care of a patient that's dying in front of you. You prioritize what you think are the most important pieces, and you filter that out.

Q Now, one thing I just want to understand, so you have a review of events, such case overview section of your report?

A Correct.

Q How did you determine what facts to include in there, or how did you include -- how did you determine

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what facts you left out?
Obviously, you can't put them all in there.
A No.
I mean, I read through the summary from DJI or DCI.
Q Yes.
A I read through the other depositions that describe the circumstances, and the best I could, I pieced together my own synopsis of the events as -- using all the resources in front of me.
Q Okay.
A I tried not to rely on one thing because, again, that's one perspective.
Q So I just have a question on page 2 here.
You describe -- Do you see where it says upon arrival?
A Yes.
Q That paragraph in the third line down says the word further discussion with this individual, directed Officer Kenny toward the second floor apartment of the same structure.
Can you just tell me what you meant there by further discussion?
A I think, from what I recall reading this, was

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that he encountered the gentleman and the gentleman pointed or said something to the fact of he went in there.
Q So when you're saying encountered, you're just saying he saw him and then --
A When he pulled up, whatever, that he saw him as he encountered him per description, the gentleman said something to him as something as I recall he went in there or something.
Q Got it.
A So that's the further discussion.
Q So further discussion isn't like a modifying prior discussion; it's just saying further after seeing him --
A After the event.
Q -- he said something, and then he directed him over?
A Right.
It probably should have been worded differently.
Q No. I just wanted to make sure that I'm clear about --
A I'm not sure there was even a discussion. It was a direction from the individual to him.

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Q Okay. Thanks. That's helpful.
So in your factual scenario here, is it fair to say that you're assuming what Officer Kenny said is correct and accurate?
MR. JOHNSON: Objection to form.
THE WITNESS: I didn't rely on just Officer Kenny. I relied on the other testimony from other individuals summarizing what Officer Kenny told them. So there were -- ultimately, does it culminate what he said, yes, it probably would, but I guess, in addition, they're taking in the facts of their evaluation of the scene, the locations, the interview of the other witness, which would be an assumption.
BY MR. OWENS:
Q Sorry. I just want to be clear.
What other individuals' testimony were you relying on about what Officer Kenny told them?
A The other depositions as well as the DCR report. That was an interview.
Q With Officer Kenny?
A Yes.
Q Right. Okay.
But the other depositions are not of individuals outside of Kenny, himself, who ever met with

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Officer Kenny, right?
A Correct.
I mean, I never interviewed Officer Kenny.
Q Sure.
A So I didn't -- I have no direct interaction with him. All I have is indirect statements from the DCR report and the other testimony as well as his that culminate into what I wrote.
Q Got it.
And so I'll just sort of -- to run on the same page going forward, when I say Officer Kenny as an account of events, I'm referring to the culmination of his interview and this deposition.
A Yes.
Q Okay. Understood?
A Yes.
Q So now are you, in describing the facts, assuming that Officer Kenny's version of events is correct?
A I'm not a -- I'm honestly not assuming anything. I'm just, as best as I can, putting together a summary of the scenario. That was it.
Q And, now, in coming to your opinions, have you assumed Officer Kenny's version of events is correct or

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accurate in any way?
A I'm sorry. Say that again.
Q In rendering your opinions later in the report, have you assumed Officer Kenny's version of events or facts are accurate and correct?
A To the best of his recollection, yes.
Q Now, you didn't note any discrepancies between Officer Kenny's account and any other evidence in the case, did you?
A That's not what I was brought in for the scope of what I was asked to do.
Q And you didn't note any inconsistencies even within, say, Officer Kenny's interview and what he said in his deposition testimony?
A Again, it was not what I was asked to evaluate.
Q Do you recall thinking to yourself that there were discrepancies between what he said in his interview to investigators and then what he said in his deposition?
A I was not focusing on that so, honestly, no, I was not -- I don't have that information.
Q So there's not a list via somewhere of like here's five things that are different from what you sort of said in the interview in March, and then by the time

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he gets to his deposition a year later, this has changed, you don't have a list like that?
A No, because that's not what I was asked to look at.
Q So one thing I just want to understand also structurally about your report is, I know you've got the analysis of the encounter, and then there are five specific opinions, and then there's a final opinion and conclusion, right?
A Correct.
Q Can you sort of explain to me how the analysis of the encounter relates to the final opinion and conclusion?
A I think you could have reversed them actually and put the opinion as just a brief two-part summary of what I took away from the testimony and the circumstances that I understood based on the chart review, and then the analysis and encounter expands on those and explains -- explains them.
Q So is it fair to say that the analysis and the encounter are the bases for these two opinions at the end?
A Yes.
Q So your first sort of basis for your two

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ultimate opinions is that Officer Kenny was involved in a highly physical and stressful series of events that resulted in the death of Tony Robinson, Jr., right?
A Yes.
Q What do you mean by highly physical?
A He suffered a blow to the head, he grappled with the individual as best I can understand from the reports, and he fell down the stairs.
Q Now, I know, I think a little bit later you discussed the fact of like physical exertion on memory and recall, right?
A Correct.
Q And you cite studies and it's your opinion that, you know, increased physical exertion can lead to errors and mistakes in memory and recall, is that right?
A I wouldn't necessarily call them errors. They -- They can lead to alterations in perception, but I don't know that I would actually opine them as errors.
Q Okay. So just taking an example, if you had an event in which there was a male interrogator and the witness reported that person was a female interrogator, you wouldn't call that an error?
A Say that again. You're asking me --
Q So, for example, in the follow-up Hope study

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where they did the second interrogation of the high-stress versus low-stress interrogations, there were, I think, two people who got the gender of their interrogators wrong?
A Right.
Q And that's an error in -- Correct?
A Yes.
So I would agree, yes, it can be an error, but it doesn't have to be an error. It can be equally I see you from this direction, and if someone else sees you from another direction, that's a different perception. We're seeing the same thing, yet I may not be seeing the mole on the side of your face if I'm on your right, and if I'm on your left, I do see it.
Q Sure. Okay. So in some sort of instances, it's sort of a subjective thing, you know, did you see the mole or not as opposed to you got the gender wrong, something like that, where it's more objective?
A I think it can be, yes.
Q And so there can be mistakes in perception, but there can also be errors related to physical -- increased physical exertion, right?
A I think the word mistake, I guess, in perception

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is what bothers me.
Q Okay.
A Because what you perceive and what I perceive in the same circumstances may be very truthful in our minds to each of us but may be very different. Whether one is a mistake or not, I can't tell you that because that's circumstantially different.
Q Got it.
So the problem, and maybe I can clarify this now, it's not that there's a mistake in the perception, it's that, you know, the way memory works isn't coded correctly so it's not right to call it a mistake in the perception end even if the result ultimately doesn't match what actually happened, is that right?
A Correct.
Q Okay. I'll be more careful about that. I get it now.
So what I'm wondering is, you know, physical exertion, to have some effect on coding which can lead to subsequent errors in identification or memory recall, the physical exertion doesn't have to be violent, right?
A Correct.
Q And it doesn't have to be --
Sorry. Let me ask it a better way.

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What sorts of physical exertion can lead to that type of an effect?
A I mean, it's been studied in exercise exertion, it's been studied in stress modeling where the officers are put through different stressful scenarios in conjunction with exertion.
Q Right.
A It's been studied in exercise alone, and we know that results in exercise alone do not always match when you add a stressful encounter to it.
Q Got it.
So I think we'll get to this a little bit later, but I want to sort of put the individual pieces together because I think it's your opinion, and you can correct me if I'm wrong, that physical exertion is one thing that can reduce the ultimate accuracy of recalling, but also stress is as well?
A Stress and emotion.
Q Right. Stress and emotion?
A Yes.
Q Then if you combine them together, then they sort of -- that can --
I'm forgetting the word. Why am I forgetting the word?

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It's X over 2.
MR. OWENS: You can go off the record. Sorry.
(Off the record.)
BY MR. OWENS:
Q So I was just trying to say, it was my understanding that your overall opinion was that high physical exertion can reduce the reliability or accuracy of ultimate event reporting on its own right, and then separately high stress can have the same effect, and then -- and those two different things can compound in a case, which is what's present here, is that correct?
A That is correct.
Q Okay. And so what I wanted to do is just for a minute talk about physical exertion, and then we'll get to the stress-related stuff in a minute, and then we'll bring them together at the end, okay?
A Okay.
Q Now, so do you have an understanding of what sorts of physical exertion can cause or have effects on -- negative effects on memory and subsequent recall?
A I don't know that I've read anything that says specifically has to be this or has to be that. I think there's, you know, loose -- there's old data out there by Bursell, who looked at -- which is not included in

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here, but that looked at heart rate, elevations in heart rate and performance, and Yerkes-Dodson came up with a Yerkes-Dodson curve, which is a view which says that you have performance degradation with elevations in heart rate so your heart rate and stress can combine to form an ideal performance, but then they degrade on the back end as your heart rate or your rate of arousal, your states of arousal increase, and there's a loose correlation that that arousal has some correlation to heart rate, but when it was tested alone as just heart rate, that never panned out, it was always the stress and the heart rate.
Q So am I right that there's no baseline for this is the amount of physical exertion at which the -- your memory is going to stop coding accurately and you might get to less reliable or inaccurate recall?
A That's correct. There is no benchmark that says this is going to happen at Point A or Point B.
Like I said, there's loose correlation between elevations in heart rate from Siddle papers that talked about fine motor skills, complex motor skills and cognitive processing related to elevations in heart rate.
Q Got it. And --

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A That comes out of my book, not out of what I've listed.
Q Okay. So the -- there's a difference between the way -- there's a difference between retrograde and antegrade memories, is that right?
A Well, I mean, antegrade is what happens from this point forward, and retrograde is what happened prior.
Q Right. Got it.
And so am I right that the -- that it's your opinion and in your opinion that the research shows that physical exertion can have an effect on recall for the accuracy of recall for events that happened even before the physical exertion?
A That's right.
Q And it can also have an effect on events after the exertion, is that right?
A Antegrade, yes.
Q So just to take an example, if a football player say were, you know, running up and down the field and asked to recall who he passed when he ran down the field, he may have trouble remembering things after running like that, but he also may have trouble remembering what happened just before that?

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A Correct.
This happens on a daily basis, right. You drive from Point A to Point B, and if I asked you the color of the car at the stoplight, you probably wouldn't even be able to remember that, and that's not even a stressful moment.
Q So the increase of stress reduces the likelihood that we'll be able to recall those details from the moment before?
A We know it's been studied in stress that stress can certainly impact one's perception of the events, and it can be antegrade and retrograde.
Q Okay. Now, the second part of your first opinion, now, you say that Officer Kenny was involved in a highly physical event.
And that was based upon the fact that, I think you mentioned, three things, a blow to the head, some type of grappling and then a fall down the stairs, is that right?
A Correct.
Q So does the physical exertion include the time before that so when Officer Kenny got out of his car?
A It certainly could depending on how high his heart rate was at that point in time and his degree of

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arousal assuming it was relatively high at that point because he was in the pursuit of someone he thought was a violent offender.
Q And did that occur at the moment before the shooting in which Officer Kenny is going up the stairs?
A Again, I've never met Officer Kenny. I don't know his physical state.
It has been reported from the point that an officer responded -- I guess the radio call to respond to a scene forward. So the stress can occur at any point in time.
Q Got it. And maybe I'll try to be clearer. I know that the stress and that can be a factor.
I think it's your testimony now that from the time the call comes in and those types of things can be happening, is that right?
A It can. I'm not saying it did. It can.
Q Sure. I'm more still just focused on the physical exertion part.
So does the physical exertion of sort of getting out of his car and walking around the house and then getting up the stairs, does that contribute, or is it just at the point that you mentioned where Officer Kenny claims there was a blow to the head?

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A I think I would say that getting out of the car is probably not a physical exertion for a normal individual. Again, I've never laid eyes on Officer Kenny. So I would probably say, no, that is not physical exertion at that point in time. It could be, but I can't really comment any further than that.
Q Right. And is the same thing with respect to him going up a flight of stairs?
A Again, I can't comment. I don't know. There's no benchmarks that define physical exertion as radiating to the human body.
Q Got it. So physical exertion -- So the first thing that you -- your opinion that would constitute physical exertion is Officer Kenny's claim that he was hit in the head?
A I think that it could go -- I think you can make the argument that the physical exertion part began when his heart rate started to elevate, and I don't know when that occurred.
Q That's consistent with your answer you gave earlier, which is it's hard to define a baseline sort of universal rule for what the physical exertion point is that would possibly affect memory?
A Unless you had a heart rate monitor on him and

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you were able to look at his physiology, his heart rate, his blood pressure and his respiratory rate at that time, I don't know that you can actually say whether he's exerted or not.

Q Right.

Now, you said there was a stressful series of events, all right, so this is the other part of your first basis for your ultimate opinions that Officer Kenny was involved in not only a highly physical but also a stressful series of events that started.

And what do you mean by that?

A Again, stress is unique to the individual, all right? A stress-inoculated person may or not react the same way as a non-stress-inoculated individual. So that has to be taken into account.

One can argue that the stress occurred the moment the radio call came in. Since I don't know what his heart rate and his physiology was at that point in time, I can't comment on that.

Q So you can't give us a specific start time for when the stress happened, began here, is that right?

A Correct.

Q And the basis for your opinion in number one of the encounter, is that, you know, reliant upon

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Officer Kenny's, you know, version of events, is that where that information comes from?

A Ultimately, he was the only one there, him and the offender, so all I can tell you is, based on what I looked back on the review of records, there was an encounter, it was physical and emotional probably for both parties, but I wasn't there so, yes, that is -- that would be my interpretation of the events.

Q And that's just Officer Kenny's interview and deposition?

A Based on records that I reviewed, yes.

Q So you next state in bold that Officer Kenny suffered a traumatic brain injury in the form of a concussion after being attacked, right?

A Yes.

Q Now, what is the basis for that opinion?

A He suffered a strike to the head reported by him, corroborated by the ER doctor who saw him with the abrasion to his head. Her diagnosis was closed head injury without loss of consciousness.

And then subsequently in -- later in his convalescence, he went through a course of cognitive rehab for post-concussive symptoms.

Q Now, you put here that Mr. Robinson attacked

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Officer Kenny, correct?

A Where?

Q We're just talking number 2 here.

A Yes. Okay. Yes.

Q And the basis for that opinion is Officer Kenny's version of what happened, right?

A That he was physically battered --

Q Yes.

A -- by taking a fist to the face, yes.

Q Right.

But you don't have any other proof of that, right?

A Just the abrasion to the head noted by the ER doctor and the diagnosis of post-head injury.

Q So, you know, if Officer Kenny had fallen down the stairs and was never hit by Tony Robinson, do you have -- do you know that one way or the another?

A I can't attest to that either way.

Q And that type of a detail is the type of a detail that the physical exertion and stress of the event could lead somebody to get wrong, is that right?

A That I would probably disagree with, and I have no data to support this other than it's usually the defining events that do in code and the secondary events

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are the ones that are lost. So a strike to the head by an individual, that is not something that's typically lost. That's usually preserved in their brain.

And I think he wanted us to -- I think it was the Hope study talked about that exact topic of high-risk events are typically prioritizing, and it's tough to say what gets prioritized and what doesn't.

Q Right.

And you don't know exactly what happened in the stairwell, right?

A No, I don't.

Q And you don't know what other things that Officer Kenny could have been prioritizing?

A When I say prioritizing, I'm talking about what his brain subconsciously prioritized as an event to encode or not encode.

Q Right.

And there's a possibility that he could have had retrograde amnesia when he was reporting that?

A Yes.

Q And, you know, so the studies that I think you cite in the paper, you know, indicate that, you know, even five minutes later, football players didn't recall what play they were on or whether they even got hit,

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right?
A Yes.
Q And so that option couldn't be ruled out there that Officer Kenny just got it wrong, fell down the stairs, has a bump on his head and thinks that he got hit by the person that he shot, is that right?
A It's possible.
Q And, now, I think we've been over this, but I just want to be clear because I'm a lawyer who goes line by line through expert reports.
The next sentence is: He was directly struck on the left side of his head and subsequently struck the wall on the right side of his head.
And that's basically solely based upon Officer Kenny's testimony, right?
A He was struck on one part of his head. He hit something because there was an abrasion there.
Q Sure.
A That's all I know.
Q Yes. But this recounting of him being struck by -- from Mr. Robinson, that's from him, right?
A Yes.
Q You've got an objective piece of evidence, the abrasion --

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A So that supports he had head trauma.
Q Right, that there was some head trauma.
But we don't know either way, you don't know to a degree of reasonable medical certainty what happened, correct?
A That's right.
Q And the -- you mentioned something a minute ago, a closed head injury.
Do you recall that?
A I do.
Q Are closed head injuries the same thing as a concussion?
A It can be.
Q Can you explain to me the differences between the two and how they can overlap?
A They're very -- Both of them are very abstract terms. Typically, a concussion is symptom-based so a closed head injury can be either symptom-based; i.e., subjective or objectively based as well with the hard findings. They're very broad terms.
Q So when you say symptom-based, you're talking about the things that the treating doctor is observing in the individual when in front of them, is that right?
A No.

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Q What do you mean by that?
A Symptom-based are subjective pieces of information offered by the individual.
Q Got it.
A Objective is what me as the physician sees.
Q Got it.
And where do sort of -- as imaging scans and stuff like that, does that fall into objective-based?
A Objective data.
Q So objective data are the things that you as the physician observe yourself, whether that be from the patient directly or through other tests that had been performed, is that right?
A Correct.
Q And the only information we have here subjective-based about Officer Kenny's condition, is that right?
A That's correct.
Q So now, is it your degree -- excuse me -- is it your opinion to a degree of medical -- reasonable medical certainty that Officer Kenny suffered a concussion as a result of this incident?
A Based on the records review and not having examined him, that's all I can deduce, yes.

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Q So, yes, to a reasonable degree of medical certainty, it's your opinion that Officer Kenny suffered a concussion from this incident?
A Based on the records, yes.
Q Now, did you consider whether or not Officer Kenny had another traumatic experience after the Tony Robinson shooting?
A So in the records that I was provided, there was no evidence of such an encounter.
Q Now, did you consider whether or not Officer Kenny had suffered a possible trauma through light sparring that he was doing when he went back to work?
A Did I consider it?
Q Yes.
A No. I saw a mention of that prior to this incident but not after this incident.
Q Did you consider whether or not Officer Kenny suffered any possible trauma when he hurt his shoulder traps subsequent to this incident?
A I don't recall.
Q Did you consider whether or not the effect of Officer Kenny's prior history of concussions and head trauma could have been at play in his later treatment?

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A There was no record of any blunt head trauma or concussive symptoms provided to me prior to this event.
Q Okay. So, you know, Officer Kenny testifies that, you know, he's been knocked out before by falling off his horse, right?
A Right.
But there's nothing in the -- there was no --
Q Got it.
A -- report that I recall seeing this.
Q Got it.
And so it's your opinion that the medical records here are sufficient for you to conclude that Officer Kenny had a concussion --
A Yes.
Q -- from this incident?
A Yes.
Q And can you point to me the portions of the records that constitute that opinion to a reasonable degree of medical certainty?
Are you looking through the small one or the big one?
A The small.
I'm looking for the ER physician report that listed the diagnosis as CHI without LOC.

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MR. JOHNSON: So that would be 229, I think.
MR. OWENS: That's right. That's it.
We're looking at Exhibit 229, Amanda.
MS. KAISER: Thanks.
THE WITNESS: Here. Final diagnostic impressions --
MR. JOHNSON: Is that labeled, Bates --
MR. OWENS: There is a Bates label.
MR. JOHNSON: What's the number?
THE WITNESS: Page 007, the bottom right corner, top right corner.
MR. OWENS: Oh, okay. So, Amanda, we're on Bates 179.
MS. KAISER: Thanks.
MR. OWENS: Got it.
BY MR. OWENS:
Q Okay. Go ahead.
A That's the first piece.
Q So hold on. Let's -- So where it says Final Diagnostics Impression, it says CHI without LOC, am I right that CHI typically in a situation like this stands for closed head injury?
A Correct.
Q Then without LOC is loss of consciousness?
A Correct.

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Q So -- And it is your testimony today that it would be appropriate for you to conclude based upon this to a reasonable degree of medical certainty that Officer Kenny suffered a concussion as a result of this incident?
A Yes.
Do you want the other one?
Q Sure.
I can help you out if you can give me a ballpark of what you're thinking about.
A It was November --
Page 214.
Q Right. Do you see the confidential Bates number in the middle?
A 44.
Q 44?
A Yes.
Q Okay.
A Post-concussive syndrome in the middle of the page, he was being treated for cognitive rehab and physical therapy related to post-concussive syndrome.
Q Okay.
A Then it's referenced on several other pages throughout by history and physical, done by the physical

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therapist.
Q So now this is -- you're pointing me to page 44, right?
A Correct. It's one of the pages.
Q OMK44?
A Yes.
Q And the --
A My understanding is the diagnosis came from Dr. Shah and he was referred to the rehab facility for rehab with regard to his post-concussive syndrome.
Q Right.
So I think that, you know, I'll just help you out here because this is not a guessing game, you know, there's OMK37?
A Okay.
Q Is this the page you were looking for?
A I mean, there were multiple pages that reference it.
Q Sure.
A This was -- The diagnosis primary was headache, and this is one of the pages that references his post-concussive syndrome.
Q Right.
So this is in August of 2015, right?

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A Yes.
Q So that would have been -- this is more than five months after the incident, right?
A Correct.
Q And you have no records about what Officer Kenny did in between April and August, correct?
A So my assumption, again, this is an assumption because I don't have records from Dr. Shah, but there is reference here that came from Dr. Shah that Dr. Shah referred him here.
When the initial referral encounter or had he been managing these on his own with Dr. Shah prior to this, I don't know.
Q Right.
So my question is, how can you opine to a reasonable degree of medical certainty that Dr. Shah got it right?
A Because all I have is a medical record.
Q So you're saying, is your testimony then, assuming these medical records are accurate, this is my -- this is your opinion?
A That is my -- Yes.
Q Right.
So but you can't vouch for the accuracy of

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these records, right?
A No.
Q So, you know, there's -- did you notice any discrepancies in the records?
A No.
But these are -- these records are -- often there's a lot of cutting and pasting that goes on from day-to-day into these records.
Q Right.
A So there's not a tremendous amount of narrative detail in the records, they're mostly prepopulated things because most of them are insurance forms to be honest with you.
Q Got it.
So it didn't concern you that Officer Kenny testified he was married and his marital status is single?
A Again, these are intake individuals that often get these things incorrect so I don't know. Those details are frequently incorrect.
Q What other details are frequently incorrect?
A In medical records is this?
Q Yes.
A People's home phone numbers are frequently

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incorrect, their addresses are put in backwards or incorrectly, things like that.
Q So I just want to be clear that your testimony is based upon assuming the accuracy of these records and then opining, yeah, he had a concussion?
A Correct.
I put more credence on the practitioners' notes than I do on the prepopulated things or what's put in by clerks.
Q And do you put more or less credence on events -- you know, the notes closer in time to the incident, or is the gap here --
A I don't think the time.
Because I don't have the medical records from the gap time from the incident to where these medical records start in August, I can't give you an opinion on what Dr. Shah saw or didn't see as far as making the recommendation for cognitive rehab.
Clearly, Dr. Shah had some concerns and some findings subjective and most likely objective, I don't know, that sent him to make the referral for cognitive rehab.
Q So what's the basis for your finding that Dr. Shah most likely had objective data?

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A He has a medical license. I have to assume that he was practicing by the standard of care.
Q And, now, when you say medical -- objective data, you are assuming that he evaluated Officer Kenny?
A Physical examination and history.
Q Right.
And there's nothing you've seen of any scans or any work like that, correct?
A Right.
Q Now, are there any other records that you relied upon for your opinion that Officer Kenny had a concussion from this incident?
A No. These were the two primary sources, I mean, listed multiply in this packet of paper refers to post-concussive syndrome several times and relates to his rehab and his cognition and his headaches.
Q Got it.
If you'll -- While we're focusing on it, if you'll go to the very, very end of the packet --
A Page?
Q -- page 116 at the bottom --
A Okay.
Q -- are you familiar with this form?
A Other than perusing it briefly, no.

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Q Now, this is a City of Madison Medical Status Report, that's what it says at the top, right?
A Okay. Yes.
Q And are you familiar with the manner in which the City of Madison or employees or doctors working for them input or fill out these forms?
A I'm not.
Q Got it.
So you see here where it says Diagnosis on this page?
A Yes.
(Off the record.)
Q Left shoulder/trapezius strain?
A Correct.
Q And would you rely on this type of a diagnosis just with this much information for concluding that Officer Kenny had a left shoulder/trapezius strain?
A All I can attest to is what I see here, and, I don't know, I don't know who this physician is, I don't know -- all I can say is that this person has an M.D. behind their name and they made a diagnosis.
Q Got it.
Now, is there anything -- in just going back to the small packet again, Exhibit 229, the page that you

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marked closed head injury without loss of consciousness, is it significant to you that the emergency room doctors included -- you know, agreed the imaging was not indicated and that the officer denied any pain and so I did not feel he has any other injury, not detected, he'll be under close observation, instructions given, does that influence your opinion one way or the other at all?
A The standard of care typically says that, if there's no loss of consciousness and no focal signs of intracranial hemorrhage based on physical exam, then a CAT scan is not warranted, and the recommendations are observation with closed head injury instructions.
Q Right.
And, you know, in this instance did you look at the -- how Officer Kenny performed on the sort of objective exams at the ER?
A I did.
Q And am I right that he got the highest score out of 15 that you can get?
A His Glasgow Coma Scale you're talking about?
Q Yes.
A Well, that does not take into account -- that's not a score to diagnose concussion. That's a score to

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diagnose whether you're awake or not. The table has a 3, and you and I are a 15 right now.
Q Got it.
So what does the -- explain if you will just clearly what exactly that scale is and how it works.
A So level of consciousness can be very subjective as most people would imagine. When we look at pre-hospital providers and we want to assess level of disability in an individual, and when I say disability, I mean their level of consciousness, we'd like to give it as best an objective measure as possible so that you have two points because one number is nothing and a trend is everything.
So if someone comes in and they are a Glasgow 15 in the field, when they get to the trauma unit, for example, here, and their Glasgow is 8, that's a significant delta in a relatively objective number. I mean, you can sway it. We typically give -- The rule of thumb for a Glasgow Coma Scale is the best score so we always error towards the best score. That's all it is.
Q Got it.
When you say delta, you mean the change, right?
A Change, right.
Q I'm right that the entire basis for your

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opinions that Officer Kenny suffered long-term consequences from the blow to the head is these medical records?
A Correct.
Q And I'm right that it's not your testimony that to a reasonable degree of medical certainty that Officer Kenny was actually struck in the head by Tony Robinson but that he did have some type of head injury after this event and that those had long-term consequences?
A What I can say is that he suffered some traumatic brain injury during the event based on the report of his testimony and that it was corroborated based on subjective findings, possibly objective, I don't know, by the ER doctor as well as his convalescence course in cognitive rehab. Understand, there's a gap in time because I have not been able to evaluate Dr. Shah's records.
Make sense?
Q It made sense. I think I might have just been asking a different question, and it was probably a bad question. So let me ask a more clearer question.
You don't have an opinion one way or the other as to whether or not Officer Kenny was actually hit by

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Tony Robinson in the stairwell, correct?
A I cannot make that distinction.
Q Okay. It is your more limited opinion that, to a reasonable degree of medical certainty, Officer Kenny suffered some type of a head injury that night that had long-term consequences, is that right?
A Based on the records I reviewed, yes.
Q And you're saying based upon the records you reviewed because it sounds like you're saying there are records that you don't have, that you haven't seen and your opinion might be different --
A And --
Q Wait.
A Sorry.
Q -- your opinion might be different if you saw different records or had more information?
A That's always a possibility.
Q Sure.
A But I did not -- I never -- I'm only going by records, and I never physically examined the individual.
Q Got it.
A Let me qualify one more thing.
I do not think my opinion would be different because you have a diagnosis at the time that the

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incident occurred, and you have the diagnosis, corroborating diagnosis, months after treating the post-concussive. So the gap in time where I don't have the records would most likely corroborate, and I expect they would corroborate since it is that doctor that referred him to the physical therapist and the occupational therapist for cognitive rehab.
Q But you don't know one way or another?
A I don't. I've never seen his medical records so I can't state anything other than Dr. Shah did refer him to cognitive rehab so Dr. Shah had to make the decision. I haven't seen anything in black and white. I can only extrapolate that Dr. Shah made the decision to refer him because the referral came from Dr. Shah.
Q Right.
You're also missing records about what Matt Kenny did during that period of time, correct?
MR. JOHNSON: Objection to form.
THE WITNESS: Correct.
But as I recall in the history from the physical therapist, he refers to these symptoms going back to the date of the incident.
BY MR. OWENS:
Q Okay. So you really want this to be

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corroborated, is that right?
MR. JOHNSON: Objection to form.
THE WITNESS: No. I'm looking at this subjectively.
BY MR. OWENS:
Q So do you know one way or the other whether or not Officer Kenny has any incentive to make up or bolster his apparent injuries from this incident?
A No, I do not.
Q And you don't know if that's something he would do or not do, right?
A I do not.
Q And you don't give him extra credit because he's a law enforcement officer, do you?
A No.
But I hold every law enforcement officer to a standard that I expect that they have integrity.
Q So are you assuming that Officer Kenny is a credible reporter?
A My default assumption would be, yes, within the realms of the risks that he has memory gaps.
Q Sure.
So is that -- is that assumption part of what forms your opinions in this case?
A No.

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I think my opinions are based on the objective information corroborated by his testimony of the events, yes. They were the only two people there, and one of them is deceased.
Q So the -- I mean, we talked about this a little bit earlier, but I just want to be really clear. In, you know, 2 Part A of your report, you say that concussions have been shown to impact both antegrade and retrograde memory of events, right?
A Yes.
Q And we went over this, but I just want to be clear about this, so that, you know, for example, if you had -- if somebody was involved in a car accident and they had got a concussion from that, the concussion might affect their memory of what happened after the car accident?
A Yes.
Q But it might also affect what happened in the lead up to the car accident, itself, is that right?
A Correct.
Q Am I right that once there's been some memory loss that there's no way to sort of determine or parse out without the, you know, introduction of outside evidence what portions of that individual's recall are

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correct, what parts that they are sort of just trying to sort of fill in the gaps?
A Correct.
Q So your next opinion, 3, that the physical exertion of the event was substantial, I know we discussed this a little bit earlier, am I right that the -- sort of the primary focus of this portion of your report is the 2013 Hope article?
A Yes, it definitely was. Not in its entirety, but yes.
(Off the record.)
MR. OWENS: Amanda, are you back?
MS. KAISER: I am.
MR. OWENS: Great.
We can go ahead and mark this as Exhibit 230.
(Exhibit 230 marked.)
BY MR. OWENS:
Q So, Doctor, this is -- am I right that this is the article that you referenced and I think you just testified to was the main thrust behind your opinions in number 3 here in your report?
A Yes.
Q Okay. And the -- I only have a couple of questions about it. You don't have any agreements with

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any of the conclusions or the results in this paper, do you?
A No.
Q And the -- I think your ultimate conclusion, I just want to understand the relationship between this and the bold sentence you have here, the results provided clear demonstration of apparent witness memory following physical exertion, right?
A Yes.
Q And you're referring here to the fact, and you can -- I'm on page 8, that participants in the -- the physical exertion condition made fewer correct responses to cued recall questions concerning the original briefing and that they also got fewer correct details on the update information, is that right?
A Correct.
Q And I think, you know, this is something that we discussed earlier, but this is sort of the basis for the discussion that we were -- some of the basis and your experience --
A Well, this -- her paper corroborates other works before hers.
Q Right.
And then you've cited the A, B, C Mather &

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Sutherland 2001 in here?
A Correct.
Q So that -- and you can correct me if I'm wrong, that is something you cited in the opinion but didn't cite in your other materials reviewed section, is that right?
A Right, because it was one level back, yes.
Q What's that?
A It was a reference of hers so yes.
Q Oh, I see. So here you cited the A, B, C by Mather & Sutherland in 2001 because --
A It was referenced in her paper, correct.
Q "In her paper," you're referring to Hope?
A Yes.
Q Got it.
So did you actually review the A, B, C Mather & Sutherland paper?
A No. I was familiar with it from previously, but I did not re-review it, no.
MR. OWENS: Just for the sake of completeness, can we mark this as Exhibit 231?
(Exhibit 231 marked.)
BY MR. OWENS:
Q All right. Now, because you said you were

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familiar with the paper, is this the one that is cited in the Hope study, is this the paper that is being referred to?
A I believe so, yes.
Q So A, B, C stands for Arousal-Biased Competition?
A Yes.
Q Now, I wanted to -- in subpoint -- or paragraph D in opinion number 3 here or basis for ultimate opinion number 3 here, you say here that the Hope study is critical because the delivery of justice relies on statements and identification provided by witnesses who experience physical exertion either in the course of their occupational duty when responding to incidents or due to the nature of the crime being perpetrated against them.
Am I right that that's a quote from --
A Right.
Q -- the conclusion of the study?
A Yes.
Q Okay. Then the thing that you've added is that bold sentence at the end?
A Yes.
Q Now, why did you include this paragraph before

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the bold stuff, and what does it mean?
A Why did I do it?
Q Yes.
A It felt right at the time I wrote the report.
Q Okay. Well, I guess, you know, I would think we've all been there, but I guess I'm wondering sort of what's the significance of this.
You know, I mean, honestly, I read that sentence, and I'm like I don't really understand what the significance of it is.
A I think what they're saying, and this is, again, my interpretation --
Q Absolutely.
A -- is that the justice system has to understand in taking into account exertional and stress-based influences when we relate them to witnesses of events.
Q Okay.
A That's all it's saying. Nothing more. Nothing less.
Q So opinion number 4 -- or paragraph 4 here, that Officer Kenny was an active witness to the event he was involved in, this, am I right, that the main thrust of this section comes from the 2015 Hope paper which compared and contrasted active officers from passive

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observers?
A Yes.
Q And so you're saying that Officer Kenny, and this is sort of the setup, right, you're saying the minute he was under a stressful event, we know he was under a stressful event because of what was going on, but also because he was an active participant, not just somebody who was watching?
A Correct.
The 2015 Hope paper was actually a very well done piece of literature, piece of science, it was peer-reviewed but actually similarly represented this scenario, although obviously not the same, it had -- it was -- it can be argued that it was similar in what it was portraying. That was it. That's why I referenced it.
Q Got it.
When you say similarly referenced this scenario --
A Stress-based and exertional-based.
Q Okay. Well, the 2015 study was not non-exertional-based, right?
A Right.
Q In fact, they tried to control to ensure that it

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wasn't exertional-based, am I right?
A It was the stress.
Q So they were trying to isolate the stress, but they didn't have the heart monitors and stuff to see if the stress would reflect other physical symptom, is that right?
A Correct.
Q Now, let's go ahead and just mark this as an exhibit. This is 232.
(Off the record.)
BY MR. OWENS:
Q Is this the 2015 Hope study?
I just want to make sure we're on the same page in terms of what we're all looking at.
(Exhibit 232 marked.)
A Yes.
Q So the -- am I right that the Hope study, well, both of them, and the other studies we've been going through don't quantify the extent of memory loss, or, you know, actually there's no way to do that, is that right?
A Well, I mean, they very eloquently looked at memory loss specific to certain events that all the officers in each group went through and looked at where

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the different groups fell apart and diverged. That's all it does. I mean, there's no way to benchmark memory. It's very subjective.
Q Right.
And especially because you also have to know whether or not the information was even coded in the first place, right?
A Well, if you're recalling it at some point in time, then it had to have been coded.
Q Sure.
But there's also, and I thought that this was one of your opinions, that misinformation can affect subsequent recall?
A Yes.
Q And so there becomes a problem with figuring out what was actually encoded during the actual incident and what was based upon what they might have learned later or assumed happened even though they have no memory, is that right?
A Correct.
Q Can you explain how that works?
A I don't think anybody knows how it works.
Q Sure.
A I think there are arguments to make that some of

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these papers have made that there's a degree of malleability or suggestibility that can influence one's recall of the events. That's all it says.

Q And there's no way to determine whether or not to disentangle the mallea -- the extent to which something was originally actually sort of input into your brain or which has been subsequently added to it through the malleability or through the information?

A You're asking what was suggested and what was --

Q Written.

A -- inserted and what was actually --

No.

Q Right.

Sort of once you throw all the ingredients in the stew, you can't pull them out individually, is that right?

A True.

Q So as a consequence, and I didn't see this in your report at all, you don't have a percent -- excuse me -- you don't have any opinions about what things Officer Kenny got right or what things that he may be misremembering or what things could be due to subsequent information that he received after the fact, right?

A I have no opinion.

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Q And, in fact, it's your opinion that we couldn't actually disentangle those things, right?

A Correct.

Q Sort of following up on the last series of questions, the inconsistencies between what happened and what is remembered in recall can happen for small details but also significant ones as well, right?

A Yes.

Q And the -- you know, I think that this is one of the papers, the one paper that you said that you reviewed specifically for -- you hadn't been familiar with was the Perspective, I believe what I remember, but it may not be true?

A Correct.

Q And, you know, it's your opinion that this statement is correct.

And that's the question. Is the following -- Is it your opinion to a reasonable degree of medical certainty that this statement is correct? In each of these research studies, inconsistencies in memory were not limited to trivial events but instead included non-trivial events such as "being shot," "being shot at," "witnessing death of a friend," "viewing human remains," "being physically injured" and exposure to

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quote "firefights."

A The paper does say that. I don't know exactly all the papers they're referring to with regards to those statements.

Q Sure. Okay.

A If someone cannot remember being shot, it's actually not -- it's possible.

Q Yes.

And it's possible -- are you familiar with the -- sort of the discussion in this paper about, you know, soldiers falsely believing they saw grenades?

A Yes.

Q And you'd agree that's a significant event, right?

A Yes.

Q And do you have any opinions that you're offering today, and I didn't see it in your report, and I just want to make sure it's not something that you were intending on opining on, but that individuals about the accuracy of their beliefs relative to the confidence they express in them?

A I'm not following.

Q All right. Bad question.

So you'll recall from the study they discussed

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instances in which soldiers who had incorrect information were actually more highly confident in that information even though it was incorrect?

A I have no opinion on that.

Q So, you know, sort of part 5 of your analysis of the encounter is sort of just what we've been discussing, right; that the -- that in a highly stressful event, individuals can create malleable and vulnerable memories that may be perceived as inaccurate by interviewers?

A Yes.

Q And there you're describing the fact that there are things that -- now, not to get semantic, but the -- I want to know does this go back to the discussion we were having about the use of the word inaccurate versus in error earlier?

So in your paragraph 5 here you say: Vulnerable memories that may be perceived as inaccurate by interviewers.

Do you see that?

A Yes.

Q And so I thought that we agreed earlier that, you know, somebody can be sort of objectively inaccurate like, you know, the example we were just discussing a

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minute ago; there were no grenades, but they believed there were grenades, or I believe he pointed a gun at me, but he never pointed the gun at me.

So those would be actually things that would be inaccurate, correct?

A Okay.

Q And this opinion includes the possibility, and included in these studies is the idea that witnesses can actually report inaccurate information, is that right?

A Yes.

Q And in these high-stress events, they can report inaccurate information even if they really believe it to be true?

A Yes.

Q And am I right in sort of paragraph 5 here that you are sort of relying most principally on this, well, I believe what I remember, but it may not be a true study?

A Well, that in combination with all the other pieces that I introduced as well as experiences.

Q There's just no citation here so I just wanted to make sure where that was coming from.

So it was the Morgan & Southwick paper and your own experiences, is that right?

A Correct.

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Q And what experiences do you have that you're drawing on for the information in this paragraph?

A I mean, there, again, reading the book and having looked at these things in the past, there have been other studies, for example, where officers have felt involved -- during involved fightings that they fired one shot when in fact they fired their entire magazine. So the objective information doesn't corroborate what they actually perceived to be true. That's all it means.

Q And here you have this statement about under high stress the brain facilitates the formation of just memories that are intended to allow us to avoid future dangers. And that seems to be a quote from the Morgan & Southwick study, right?

A Right.

Q And --

A That should have actually been cited, yes.

Q We don't have a way, there's no way to determine what was in the gist memory sort of objectively, right?

A Correct.

Q And there's no way to sort of know sort of objectively or externally what precisely the brain might have been focusing on that would have caused them to be

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thinking about avoiding future dangers, right?

A Correct.

Q Okay. So these, I think, we discussed this earlier, 1, 2, 3, 4, 5, which sort of marks through with some discussion, are the bases for your final opinion and conclusions 1 and 2, right?

A Yes.

Q And you hold opinions 1 and 2 to a reasonable degree of medical certainty?

A Yes.

Q And the first is that Officer Kenny suffered both the physical and emotional trauma in the form of a traumatic head injury and the elicited stress and exertional response associated with the event?

A Correct.

Q And that's based upon the studies we've talked about today, your experience, his medical records and his testimony?

A That is correct.

Q Now, the second opinion you have is that Officer Kenny's recollection of the events is not an intentional attempt to deceive or alter the events to better his position, but, in fact, they are attributable to the malleable and vulnerable nature of memories

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associated with this highly traumatic event?

A Correct.

Q Okay. So can I summarize this as your opinion to a reasonable degree of medical certainty that Officer Kenny is not lying?

A Yes.

Q So you're vouching for the credibility of Officer Kenny?

A No.

I am giving him the benefit of the doubt that what he is reporting is not an intentional lie but can be also -- but can be explained by alterations in his memories.

Q Could it be a lie?

A It could be.

Q But you're giving he him the benefit of the doubt and saying here's an explanation for it?

A I'm saying that the reporting of events can be -- any alterations in his reporting of events that may be found inconsistent can be explained by the data that we have here with regards to stress and exertion.

Q So I just want to be really clear. So it's your opinion that the inconsistencies can be explained?

A Can be --

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Q Okay.
A -- possibly explained.
Q Right.
So then we should maybe just change the words in the sentence here because the way I read it, it says that -- you know, it's not stated in the can be, it's stated in the is in a declarative form.
Would you agree with that?
A Yes.
Q So are you changing your opinion today to back off of the it is an intentional attempt to deceive or just that we don't know one way or the other?
A I'm not here to evaluate his integrity.
Q Okay.
A The statement gives him the benefit of the doubt that he is not intentionally attempting to deceive, but the intent of the statement is to say that any inconsistencies can easily be explained by the exertion and stress of the moment.
Q Got it.
But you still stand by this entire statement?
A With the understanding that I will qualify it here that I'm not vouching for his integrity.
Q But you don't know one way or another whether or

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not Officer Kenny is trying to intentionally deceive anyone?
A I am not.
Q In fact, that's beyond the scope of the reports that we've been discussing, right?
A Correct.
Q And, in fact, you'd agree that Hope, in especially the 2015 studies, emphasizes that officers may have reasons to give legally justifiable reason versions of events to try to avoid legal liability, right?
A I can give you an opinion on that either way.
Q Well, I mean, that's -- my question wasn't about your opinion.
That's something that's in the Hope study, itself, right?
A Say it --
Q That's something that's in the Hope --
A What exactly is in the Hope study?
Q I'll clarify it. Let me back up two steps.
That they acknowledge that there is a possibility that officers may give justifications or reasons or versions of events that they know will allow them to say a use of force, of legal force, is legally

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justified, right?
A That can -- That statement is in the Hope study, and it's also -- it can be interpreted by anybody, yes.
Q Right.
A If you want to question the validity or the virtuality of the integrity of an officer.
Q Got it.
And you're not here to do that?
A No.
Q Are there any propositions that you sort of disagree with in the Hope study in their discussion of this aspect of the situations of their results?
A No.
I just -- I feel that one study does not answer -- answer all the questions that you're posing or that the world poses on a regular basis and that you have to take every piece of data with a degree of respect for the limitations that the data offers. That's all I can say.
You know, that's why there are multiple pieces of information that influence my decision, and not everything has an objective answer to it as much as we would like that to be.
Q Got it.

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So what I'm wondering is whether or not you disagree with any of their discussion.
I'm not saying it's the end all, be all.
A There wasn't anything that stood out that I absolutely disagree with.
I think multiple possibilities could exist in all of these realms.
Q Sure.
A And I don't think that there is one stance or another that I recall physically saying that's absolutely wrong.
Q Okay. Well, so if you'll look with me at --
A You're on --
What study are you on?
Q The 2015 one. So this would be 232. And I'm looking at the top of -- excuse me -- the bottom of page 28.
The last two words on the page: In sum.
A Okay.
Q And then it carries over to the next page.
"In sum, it is not possible to determine whether this error reflects a memory distortion or post hoc justification informed by outcome and bias."
Do you disagree with that statement?

A No. I absolutely agree with it.
Q Can we mark Exhibit 233?
We can go off.
(Off the record.)
BY MR. OWENS:
Q This is what's been marked as Exhibit 233.
And, Doctor, I just wanted to make sure that this is the same paper that you've cited here on page 3 of your report.
(Exhibit 233 marked.)
A This is it. This is it.
Q Can I just like have a couple minutes? Then we may be out of here.
MR. JOHNSON: Amanda, do you have questions?
MS. KAISER: No.
MR. JOHNSON: I don't know what you want her to do. It doesn't matter to me.
MR. OWENS: I just need --
MR. JOHNSON: Collect your thoughts.
MR. OWENS: Yes.
MR. JOHNSON: Go ahead. No problems.
(Off the record.)
MR. OWENS: I think that's all I've got.
MR. JOHNSON: Amanda, do you have any questions?

MS. KAISER: I do not.

MR. JOHNSON: Okay.

MR. OWENS: Doctor, you have the right to review the transcript and read and sign it if you'd like, or you can waive your signature. It's up to you.

THE WITNESS: I'll waive. Waiving is fine.

MR. OWENS: All right. Thanks.

- - - - -

STATE OF ILLINOIS)
) ss:
COUNTY OF C O O K)

The within and foregoing deposition of the aforementioned witness was taken before ROBBIN M. OCHENKOWSKI, C.S.R., and Notary Public, at the place, date and time aforementioned.

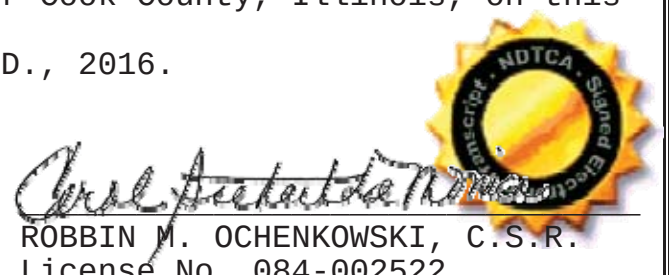
There were present during the taking of the deposition the previously named counsel.

The said witness was first duly sworn and was then examined upon oral interrogatories; the questions and answers were taken down in shorthand by the undersigned, acting as stenographer and Notary Public; and the within and foregoing is a true, accurate and complete record of all of the questions asked of and answers made by the aforementioned witness, at the time and place hereinabove referred to.

The signature of the witness was waived by agreement of counsel.

The undersigned is not interested in the within case, nor of kin or counsel to any of the parties.

Witness my official signature and seal as Notary Public in and for Cook County, Illinois, on this 1st day of November, A.D., 2016.



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Witnesses in action: The effect of physical exertion on recall and recognition

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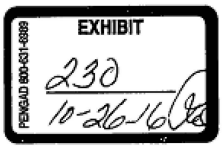

Abstract

Understanding memory performance under different operational conditions is critical in many occupational settings. In order to examine the effect of physical exertion on memory for a witnessed event, law enforcement officers engaged in a high intensity assault exercise and were then exposed to a live occupationally-relevant scenario. Physically exerted participants showed impaired recall and recognition performance in comparison to a non-exerted group. Specifically, exerted officers provided significantly less accurate information concerning critical and incidental targets encountered during the scenario. Exerted participants recalled less briefing information and provided fewer updates than non-exerted participants. Exertion was also associated with poorer identification performance on a target present lineup task. Results are discussed in relation to arousal-based competition accounts reflecting 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.

Witnesses in action: The effect of physical exertion on recall and recognition.

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. 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.

Here we report the first study designed to test eyewitness recall and recognition memory 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 tested. In line with findings 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 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 (i.e. during or on the immediate cessation of exercise) does not appear to be systematically related to memory performance (see McMorris et al., 2011). Therefore, in line with arousal theories, 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. There was no difference between conditions for self-reported frequency of recreational physical exercise, $t(50) = -1.13$, $p = .27$, $d = .32$.

Materials

Pre-deployment briefing. The pre-deployment briefing contained information about three recent armed robberies in the area (e.g., location of crimes, modus operandi). Official 'updates' to the original briefing contained 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 that included a clear color photograph of the target was prepared. 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 environment). The front door opened into a furnished lounge area and a second door led through to a bedroom. Four weapons (semi-automatic rifle, knife, shotgun and handgun) were placed in the main lounge area. The semi-automatic rifle and a knife were positioned centrally (in easy reach of the target). All weapons were clearly visible from the pre-determined vantage point.

Procedure. Test sessions took place within a police training facility. Participants attended in pairs and were randomly allocated to either the Physical Exertion (PE) or Control condition. After being fitted with Polar Heart Rate monitoring belts, participants were instructed to read the briefing carefully as it provided relevant information for their operational duties. Then, while the Control participant observed, the officer in the PE condition, supervised by a qualified physical fitness instructor, began a high intensity assault on a gym bag. PE 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 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 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 pre-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 exerted participant left the scene immediately and the Control participant took part in the scenario via the same access route. All participants took up the same vantage point, facilitating a clear central view of the inside of the trailer and critical target, during the scenario. 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).

After comparable delays, participants completed the memory tasks individually. Firstly, participants responded to 20 cued recall questions concerning the briefing information. Two questions targeted information that had been altered by the briefing updates. Secondly, participants were asked to report everything they could remember about the incidental target, the critical target and the 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 to ensure 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 made fewer correct responses to cued recall questions concerning 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 briefing updates with 84% of Control participants but only 52% of PE participants providing correct update information, χ^2(1, 50) = 5.88, *p* < .05, φ = -.34. Of participants who provided correct update information, the majority (88%) provided 'additional information' (only four responses included the 'amendment' update). 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 Control participants, *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 displayed impaired 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. It should also be noted that the current study tested identification performance using a target present lineup. Future research should examine accuracy for target absent arrays in order to fully determine the effect of exertion on identification performance (see Wells & Penrod, 2011).

Results also reveal an interesting effect of physical exertion on information encoded shortly before physical activity. PE participants showed poorer recall 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). Here, 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 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. 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

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Arousal-Biased Competition in Perception and Memory

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Abstract

Our everyday surroundings besiege us with information. The battle is for a share of our limited attention and memory, with the brain selecting the winners and discarding the losers. Previous research shows that both bottom–up and top–down factors bias competition in favor of high priority stimuli. We propose that arousal during an event increases this bias both in perception and in long-term memory of the event. Arousal-biased competition theory provides specific predictions about when arousal will enhance memory for events and when it will impair it, which accounts for some puzzling contradictions in the emotional memory literature.

Keywords

arousal, emotional memory, biased competition, attention

> Selection is the very keel on which our mental ship is built. And in this case of memory its utility is obvious. If we remembered everything, we should on most occasions be as ill off as if we remembered nothing.
>
> —William James, *The Principles of Psychology* (1890, p. 680)

The brain's ability to prioritize information allows us to think and take action without being overwhelmed by external stimuli or internal thoughts and feelings. Attending to what is important while ignoring extraneous detail can enhance performance in challenging situations, such as facing a difficult task or a threat to one's safety. A wide range of cognitive and emotional challenges increase autonomic arousal, affecting heart rate, galvanic skin response, and pupil dilation. Even something as simple as an emotional picture shown for a few seconds can increase autonomic arousal (e.g., Bradley, Miccoli, Escrig, & Lang, 2008). Emotional stimuli and cognitive challenges also increase levels of stress hormones such as epinephrine and cortisol.

Given the importance of focused attention in challenging situations, it would be helpful if arousal increased how selective the brain is when processing information. Many studies have examined the role of arousal in the selectivity of information processing, eliciting arousal in a variety of ways, including via emotional stimuli, stress, and administration of stress hormones. Some prominent characterizations of how arousal affects the selectivity of memory are listed in Table 1. These arousal effects on memory are diverse, and no previous theory we are aware of can account for them all. Furthermore, even at the specific level, each separate arousal effect characterization (such as "arousal induces retrograde amnesia") faces contradictory findings in the literature (see Table 1). In this article, we propose a new theory of arousal-biased competition to account for how arousal affects memory selectivity. We start by outlining the theory and how it operates in perception. We then turn to the domain of memory to explain how the theory accounts for the eclectic and apparently contradictory findings outlined in Table 1.

Arousal-Biased Competition

What we call *arousal-biased competition* (ABC) is the notion that arousal (whether elicited by external stimuli, internal thoughts, or stress hormones) modulates the strength of competing mental representations, enhancing memory for items that dominate the contest for selective attention. This competition for representation begins during perception and continues into long-term consolidation. During perception, arousal biases competition in favor of perceptually conspicuous or goal-relevant stimuli. Arousal then enhances memory consolidation

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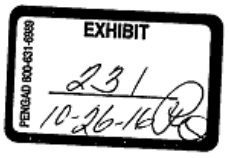

Table 1. Prominent Characterizations of How Arousal Affects Memory, With Related Findings

Arousal effect	Finding(s) illustrating the effect	Inconsistent finding(s)
1. Arousal leads to memory narrowing	Emotional arousal enhances memory for central details at the cost of peripheral details. This has been interpreted as evidence that arousal causes memory narrowing (Burke, Heuer, & Reisberg, 1992; Christianson et al., 1991). A related phenomena is the weapon-focus effect, in which people remember the weapon when witnessing a real or simulated crime but forget other scene details (Steblay, 1992).	Thematically induced emotion enhances memory for noncentral information (Laney et al., 2004). Also, an arousing picture shown in one location on the screen impairs memory for background information more than for spatially peripheral but foreground information (Mather et al., 2009).
2. Emotional arousal enhances memory for gist but not detail	Interspersing emotional slides throughout a slide show increases the degree to which participants recall the gist rather than the details of certain target (nonmanipulated) slides, indicating that emotional arousal enhances memory for the gist but not details of events (Adolphs et al., 2005).	Memory is better for the specific details of emotional objects than for the details of nonemotional objects (Kensinger et al., 2006), and whether emotion enhances or impairs memory for the gist and details depends on how attention was directed during encoding (Kensinger, Garoff-Eaton, & Schacter, 2007).
3. Arousal enhances within-object memory binding	Emotional arousal enhances memory of intrinsic features of an object but does not enhance memory for associations between items (Kensinger, 2009; Mather, 2007).	Participants asked to learn word pairs and then given the first word in the pair as a cue to retrieve the second word were better at recalling neutral words paired with emotionally arousing words (Guillet & Arndt, 2009).
4. Arousal creates retrograde amnesia	Arousing words or pictures can lead to retrograde amnesia, in which preceding neutral words or pictures are more likely to be forgotten (Knight & Mather, 2009; Strange et al., 2003)	Arousing pictures can lead to retrograde enhancement, in which preceding pictures are more likely to be recalled (Anderson et al., 2006; Knight & Mather, 2009).
5. Arousal enhances consolidation for emotional items	Postencoding arousal enhances memory for emotional stimuli more than for neutral stimuli, indicating that arousal enhances memory consolidation of emotional, but not neutral, information (Buchanan & Lovallo, 2001; Cahill et al., 2003).	Arousal experienced after exposure to neutral information can enhance memory for that neutral information when tested a couple of days or a week later (Abercrombie, Kalin, Thurow, Rosenkranz, & Davidson, 2003; Anderson et al., 2006; Andreano & Cahill, 2006; Knight & Mather, 2009; Nielson & Powless, 2007; Nielson et al., 2005; see also Maheu et al., 2004).

Note. See text for how arousal-biased competition accounts for consistent and inconsistent findings.

for the most conspicuous or goal-relevant stimuli, regardless of whether those stimuli were arousing or not. ABC theory builds on existing biased-competition models of attention that we describe in the next section.

Biased Competition in Nonarousing Situations

Imagine scanning a crowd of faces to find a friend. How can you find a specific face? Both bottom–up cues from the scene (such as a hand waving) and top–down goals (such as finding a friend with blonde hair) can bias attention toward particular faces, increasing the processing resources devoted to that face (Beck & Kastner, 2009). Once the friend's face is located, another challenge is to maintain that face's representation and relative location despite potential distraction from the rest of the scene. In this section, we review research on selective attention and biased competition in nonarousing situations.

One intuitive metaphor of selective attention is that of a spotlight, in which attention is focused on one region of the visual field, with stimuli outside that region having little influence (Posner, Snyder, & Davidson, 1980). However, there are many ways in which selective attention does not conform to this metaphor (Cave & Bichot, 1999). For instance, the set of features targeted for selective attention cannot always be defined based on feature locations. Instead, attention is often object based (for a review, see Scholl, 2001). So, for instance, when two transparent objects overlap, attention may be directed to one object, impairing processing of the other object (e.g., O'Craven, Downing, & Kanwisher, 1999; Valdes-Sosa, Cobo, & Pinilla, 2000).

The biased-competition theory of attention accounts for these object-based effects by assuming that objects in the visual field compete for neural representation (Bundesen, 1990; Bundesen, Habekost, & Kyllingsbaek, 2005; Deco & Rolls, 2005; Desimone, 1998; Desimone & Duncan, 1995; Kastner & Ungerleider, 2001; Miller & Cohen, 2001). Biased-competition theory proposes three basic ideas (Beck & Kastner, 2009; Duncan, 2006). First, the competitive nature of visual processing means that a stronger neural response to any one visual object comes at the expense of weaker responses to others. Second, top–down goals or signals bias competition. Third, competition is integrated across brain regions, so that a visual object that dominates in the visual cortex will likely dominate in other regions such as the prefrontal and parietal cortices.

Biased competition has been observed in single cell recordings from the inferotemporal cortex of monkeys. This high-level visual area has neurons that selectively respond to

complex object properties, contributing to object recognition. A single-cell recording study identified, for each recorded cell, a picture that produced a strong response (Picture A) and a picture that produced a weak or no response (Picture B; Chelazzi, Duncan, Miller, & Desimone, 1998). When Picture A was shown alone, the cell increased its firing rate dramatically. However, when A and B were shown together, the cell initially showed a firing rate in between that seen for A and B by themselves. A short time (300 ms) later, the firing rate diverged for the 2-picture presentations depending on the monkey's current goal. If Picture A was the target, the firing rate for that cell rose to same rate as when A was presented by itself. If Picture B was the target, the firing rate decreased to the same rate as when B was presented by itself.

These data illustrate two important points. The first is that competition from Picture B interferes with the response to the preferred picture, as indicated by the lower initial response to Picture A in the two-picture presentation than in the A-only presentation. The second important point is that the competition in the two-picture presentation conditions is biased by top–down goals, so that more behaviorally relevant information wins the competition for representation.

fMRI studies also reveal neural response patterns consistent with biased competition (e.g., Kastner, De Weerd, Desimone, & Ungerleider, 1998; Reddy, Kanwisher, & VanRullen, 2009). As in the single-cell recording studies (Chelazzi et al., 1998; Chelazzi, Miller, Duncan, & Desimone, 2001), directing attention to one of multiple objects reduces the suppressive effects of the competing objects, bringing activation closer to levels seen with just one object presented alone (Kastner et al., 1998). During directed attention, a frontoparietal attentional network (including the anterior cingulate cortex: ACC) generates top–down biasing signals that modulate activity in sensory regions (Dehaene, Kerszberg, & Changeux, 1998; Hampshire, Duncan, & Owen, 2007; Hon, Epstein, Owen, & Duncan, 2006; Hung, Driver, & Walsh, 2005; Miller & Cohen, 2001).

Competition for mental representation continues after stimuli disappear. For instance, in one study, participants saw a face and a scene next to each other on the screen (Johnson & Johnson, 2009a). After the pictures disappeared, participants were cued to think about one of the two pictures. When compared with a control condition in which they were not asked to refresh either picture, thinking about the scene increased activity in the parahippocampal place area, a scene-selective area, whereas thinking about the face suppressed activity in the parahippocampal place area (see also K.J. Mitchell, Johnson, Higgins, & Johnson, 2010). Thus, top–down goals bias competition among mental representations even when there are no external perceptual stimuli.

The selectivity supported by biased competition should be particularly important during stressful or threatening situations, when distractions may be dangerous. Indeed, a number of studies provide evidence that the arousal from stress or a threat biases competition in perception and attention. However, before turning to the evidence for ABC, we first discuss *priority*, a key concept for our theory.

Routes to Stimuli Priority

In ABC, a particular item's priority determines whether arousal will enhance or impair perception of that item. Arousal amplifies the effects of competition, improving perception of high priority information and weakening perception of low priority information. This leads to the question of what determines priority. As described below, bottom-up sensory influences (the waving hand in the crowd) and top–down cognitive factors such as goal relevance and expectations (the search for a blond-haired friend) can independently determine priority (for a review, see Fecteau & Munoz, 2006). Other factors that predict priority, such as unexpectedness, emotional relevance, and social relevance, reflect interactions of sensory and cognitive signals.

Bottom–up

The bottom–up route to priority is via perceptual contrast. Targets in an array "pop out" when they differ from their context, whether that difference is in orientation, motion, luminance or color (Nothdurft, 2000). Using this fundamental rule about what draws attention, computational models can predict where eye fixations will land on an image by analyzing the image's center-surround contrast at every location (Berg, Boehnke, Marino, Munoz, & Itti, 2009; Itti & Koch, 2000). In these salience map models, the center-surround contrast is computed for a variety of different features (e.g., color, intensity, orientation, flicker, and motion) at different spatial scales and all the separate estimates of within-feature contrast are assembled into a global saliency map. Similar contrast algorithms can predict attention to auditory stimuli (Kayser, Petkov, Lippert, & Logothetis, 2005).

In these models, a center-surround differentiation process mimics properties of local cortical inhibition. When the contrast is high between the center and the surround, activation for the center is increased and activation for the surround is inhibited. The result of several iterations of this competitive process is that only a few locations on the feature maps remain active (Fig. 1A). However, if the image consists of a set of items with equal contrast (Fig. 1B), the center-surround competition process leads all peaks to inhibit each other suppressing the entire map.

ABC predicts that arousal will amplify the effects of contrast by boosting excitation for the highest contrast item and inhibition of the surrounding context, leading to an even sparser set of active locations in the saliency map than under nonarousing conditions. But those that do survive will have greater activation levels.

Top–down

Priority is also determined by top–down factors such as goals, knowledge, and expectations. In particular, stimuli that are relevant to current goals gain priority over irrelevant stimuli. Many theoretical models posit that goal-directed attention

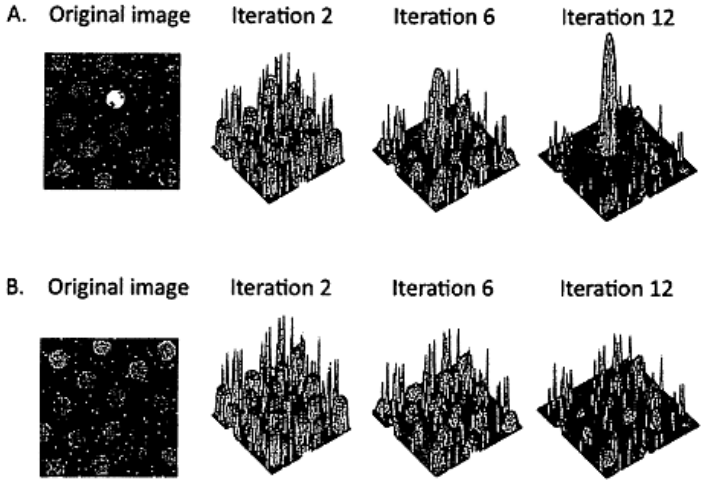

Fig. 1. Output from Itti and Koch's (2000) computational model to derive a saliency map from feature contrast. In Panel A, one strongly activated location is surrounded by weaker ones. Iterative spatial competition leads this location to gain further strength while suppressing surrounding regions. In Panel B, numerous strongly activated locations inhibit each other, leading to suppression of all locations. Figure adapted from Itti and Koch (2000).

enhances and suppresses representations of stimuli during perception (for a review, see Walther & Koch, 2007). CoC Consistent with such models, researchers have found that directing people to remember scenes and ignore faces while they look at pictures of each leads to above-baseline activity in the parahippocampal place area, a scene-selective brain region, whereas directing them to ignore scenes and remember faces leads to below-baseline activity in the parahippocampal place area (Gazzaley, Cooney, McEvoy, Knight, & D'Esposito, 2005). This reveals both top–down enhancement and suppression of mental representations of the perceived scenes. Furthermore, internal representations of previously perceived stimuli are also enhanced if they are goal relevant or suppressed if they are goal irrelevant (e.g., Johnson & Johnson, 2009b). ABC predicts that arousal will increase priority for goal-relevant stimuli and decrease priority for goal-irrelevant stimuli.

Surprise

Although perceptual contrast and goal relevance are independent factors, other predictors of priority are determined by interactions of bottom–up perception and top–down reflection. For instance, novel and unexpected stimuli are prioritized due to the mismatch between perceptual input and prior knowledge (Itti & Baldi, 2009; Ranganath & Rainer, 2003). Analogous to salience maps for perceptual contrast, a computational model can quantify how surprising each location on a feature map is by comparing beliefs about what is likely to be in that location before and after seeing the information (Baldi & Itti, 2010).

Emotional relevance

Emotional relevance is another contributor to priority that has bottom–up and top–down components. Many studies demonstrate that emotional stimuli stand out more than neutral stimuli. For instance, when a neutral and an arousing picture are simultaneously presented, one's eyes are more likely to first fixate on the arousing picture and then fixate more frequently on it (Knight et al., 2007; LaBar, Mesulam, Gitelman, & Weintraub, 2000; Rosler et al., 2005). This bias favoring the arousing picture even occurs under direct instructions to ignore the arousing items (Nummenmaa, Hyona, & Calvo, 2006). Viewing emotional stimuli also increases activity in visual brain areas associated with object recognition, such as the fusiform and inferotemporal cortices (Sabatinelli, Flaisch, Bradley, Fitzsimmons, & Lang, 2004; Taylor, Liberzon, & Koeppe, 2000), and it leads to an early posterior negativity in event-related brain potential studies (Schupp, Flaisch, Stockburger, & Junghofer, 2006), suggesting prioritized visual processing of emotional stimuli. Similar results have been observed in other sensory systems: Emotionally evocative sounds increase activity in the auditory cortex (superior temporal gyrus; Zald & Pardo, 2002) and tasting pleasant or aversive liquid solutions increases activity in the taste cortex (fronto-opercular insula; O'Doherty, Rolls, Francis, Bowtell, & McGlone, 2001).

Debate about why emotional stimuli have enhanced priority has yielded evidence for both bottom–up and top–down mechanisms. For instance, a study in which participants

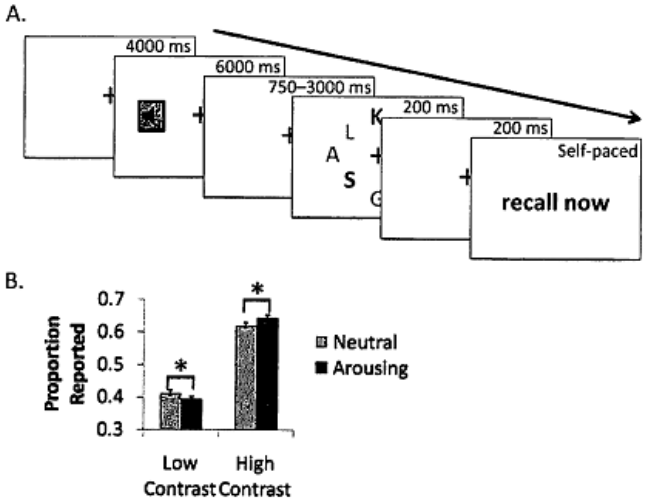

Fig. 2. A: The sequence for each trial in Sutherland and Mather (2011). B: Arousing sounds increased the proportion of dark letters reported and decreased the proportion of light letters reported.

detected one emotional face in an array of neutral faces found that computationally modeled bottom–up visual saliency (using the model shown in Fig. 1; Itti & Koch, 2000) predicted face detection speed (Calvo & Nummenmaa, 2008). A study examining event-related brain potentials in response to difficult-to-see faces reveals top–down influences (Lee et al., 2010). When participants looking at a neutral face thought they saw an emotional face, activity in posterior visual regions showed the same type of enhanced activity seen during actual emotional face perception. Thus, due to a mixture of factors, including bottom–up perceptual contrast and top–down cognitive factors, emotional stimuli are likely to have high priority. Furthermore, arousal (evoked either by those same stimuli or by another source) should increase the competitive advantage of the emotional stimuli over lower priority stimuli.

Social relevance

Finally, social relevance can also increase stimulus priority. When asked just to look at a visual scene that includes human faces, people frequently fixate on the eyes (Birmingham, Bischof, & Kingstone, 2009a, 2009b)—a tendency that is not accounted for by computationally modeled bottom–up visual saliency (Itti & Koch, 2000). People's default interest in the social information other people's eyes convey may be the mechanism underlying this type of priority (e.g., Birmingham, Bischof, & Kingstone, 2008). Information-seeking goals may lead eyes to attract more attention than would be predicted from their perceptual contrast.

Evidence for ABC in Perception

In this section, we focus on ABC in perception, reviewing evidence that arousal amplifies the bottom–up salience and the top–down competitive advantage of high and low priority stimuli. We discuss how ABC can account for arousal effects in binocular rivalry and tracking multiple items, as well as the brain mechanisms of how arousal modulates top–down priority.

ABC amplifies perceptual contrast

To test whether arousal increases the competitive advantage of high contrast (and therefore salient) over low contrast (and therefore less salient) stimuli, we played arousing or nonarousing sounds before briefly presenting a circular array of eight letters (Fig. 2; Sutherland & Mather, 2011). Three of the letters were printed in high contrast dark grey on the white background, whereas the other five letters were printed in lower contrast grey. Participants then reported which letters they saw.

As expected, participants were more likely to report the high contrast letters than the low contrast letters. More interesting, however, was that hearing an arousing sound before viewing the letters significantly increased reporting of high contrast letters and decreased reporting of low contrast letters. Thus, arousal amplified the competitive advantage of perceptually salient stimuli and the competitive disadvantage of less salient stimuli. In a second experiment, participants were randomly assigned to have a fixation interval between the arousing sound and the letter presentation that ranged from 750–3000 ms (a replication of the first experiment) or to have an interval that ranged from

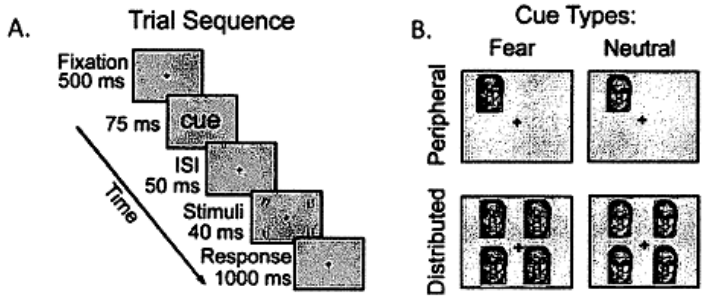

Fig. 3. A: Trial sequence from Phelps et al. (2006). Participants indicated whether one of the four gratings was tilted or none were tilted. B: A preceding cue varied in its spatial location and in whether it was a fearful or neutral face. ISI = interstimulus interval. Figure adapted from Phelps et al. (2006).

4000–6000 ms. In the short-interval condition, the ABC effect replicated, but there was no significant effect of arousal in the long-interval condition. Thus, for only a brief period after their presentation, arousing auditory stimuli bias competition in favor of high contrast visual stimuli.

In that study, higher and lower contrast stimuli competed for mental representation. However, if a low contrast stimulus is shown alone and is the target of attention, ABC should increase its priority, as it is the most strongly activated stimulus in the display. Indeed, several studies indicate that presenting an arousing cue can make subsequent low contrast stimuli presented alone on the screen more easily perceived (Laretzaki, Plainis, Argyropoulos, Pallikaris, & Bitsios, 2010; Padmala & Pessoa, 2008; Phelps, Ling, & Carrasco, 2006). For instance, when participants with low trait anxiety were told to anticipate receiving 1–3 electric shocks during a 2-min experiment block, they showed a shorter P100 latency of the visual evoked response when shown an 8% or 12% contrast grating (Laretzaki et al., 2010). The P100 latency was shorter under shock anticipation for both gratings, but even shorter for the higher contrast (12%) grating than for the lower contrast (8%) one. It is interesting to note that participants with high trait anxiety did not show any significant effect of anticipating shock. Future studies are needed to see if these participants were already too aroused at baseline to see any further effect or whether they might have been more internally focused rather than task focused (they rated their alertness significantly lower than did the low-trait-anxiety participants). An fMRI study revealed that this type of arousal-enhanced perception of target items is associated with increased activation in areas V1–V4 of the visual cortex (Padmala & Pessoa, 2008). In this study, an auditory cue on each trial indicated whether or not the trial might involve a shock. Anticipating a shock-enhanced detection of low-contrast gratings, an effect that was associated with greater activity in the early visual cortex.

In a similar study (Phelps et al., 2006), participants tried to identify whether one of the four gratings was tilted to the left or to the right. The gratings were shown for only a brief period (40 ms; see Fig. 3A). Before the gratings, Phelps et al. displayed a cue consisting either of a fearful or a neutral face presented in one location or in all four potential grating locations (Fig. 3B). Of course, there was an effect of spatial cueing: Showing just one face (either neutral or fearful) in the same location as the upcoming tilted grating increased accuracy. There was also an effect of emotion: When a fearful face, rather than a neutral face, was used to cue the relevant grating, participants could identify the tilt direction at lower levels of contrast, consistent with the studies reviewed above.[1] But an additional intriguing aspect of this study was the finding that the emotional enhancement was greater when the cue consisted of just one face in the same location as the upcoming tilted grating than when the cue was four faces of the same type. Thus the effects of emotion and attention were not only independent effects, they interacted to enhance perception more than either effect did on its own.

ABC amplifies the effects of goal relevance

Consistent with ABC theory, a study using event-related brain potential measures revealed that arousal amplifies the effect of goal relevance, especially during stimulus evaluation phases of processing (Schupp et al., 2007). In this study, participants viewed a rapid slide show of pictures consisting of erotic pictures of people, neutral pictures of people, and scenes of mutilation or injury. Participants were either asked to count the erotica, neutral people, or mutilation pictures. This counting task manipulated which type of picture was the focus of attention. An ERP component thought to reflect the process of stimulus evaluation called the P3 (appearing about 200–350 ms after stimulus onset) was more pronounced for each stimulus type when it was the focus of attention, but this attention effect was greater for the erotica and mutilation pictures than for the neutral pictures.

Of particular interest are studies that separate the arousal or stress-inducing stimulus from the competition for attention.

These studies indicate that arousal enhances perception for the highest priority stimulus and reduces perception for what has lower priority—even when the high priority stimuli are not themselves arousal inducing. For example, Hockey (1970b) had participants perform a central pursuit-tracking task, while also indicating whenever one of six lamps signaled. The lamps flanked both sides of the central tracking task display. Lamps closest to the display were considered "central," whereas lamps furthest from the display were considered "peripheral." Some participants heard constant loud noise (100 dB), whereas others heard less intense noise (70 dB). In the unequal condition, the central lamps were more likely to signal—and were therefore more goal-relevant—than were the peripheral lamps. Performance in the two noise conditions did not differ across the central and peripheral lamps in the equal condition, but in the unequal condition in which central lamps were more likely to signal, noise-induced arousal led to faster responses to the central lamps and slower responses to the peripheral lamps. In other words, the noise-induced arousal increased existing biases toward the goal-relevant lamps at the cost of the goal-irrelevant lamps but did not increase the bias toward spatially central cues when spatial layout was not linked with goal relevance (see also Hockey & Hamilton, 1970).

ABC theory indicates that a central spatial location does not necessarily give a stimulus priority. Instead, goal relevance interacts with the perceptual features of competing stimuli to determine stimulus priority. Consistent with this idea, when arousal is manipulated via electric shock, aroused subjects show greater processing of goal-relevant but spatially peripheral cues than do control subjects (Cornsweet, 1969).[2] Moreover, when participants are asked to classify stimuli on one dimension, they are better able to ignore irrelevant stimulus characteristics when stressed than when not stressed (Chajut & Algom, 2003). These findings suggest that arousal and stress enhance the priority of goal-relevant information, while diminishing the priority of goal-irrelevant information, which should have consequences for later memory (for more about the possible role of goal relevance in emotional memory narrowing effects, see Levine & Edelstein, 2009).

At first glance, other findings appear to contradict the idea that arousal enhances the priority of goal-relevant information. For instance, when participants compare the similarity of two houses in the presence of two distracter faces, their performance drops when the facial expressions are emotional (Vuilleumier, Armony, Driver, & Dolan, 2001). But such results are expected when an arousal-eliciting stimulus is in direct competition with the task-relevant stimulus, because emotionally arousing stimuli themselves have high priority. ABC predicts that if arousal is induced in a way in which the arousing stimulus is not in direct competition with the task-relevant stimuli, then the processing of neutral goal-relevant stimuli should be enhanced (e.g., Chajut & Algom, 2003; Cornsweet, 1969; Hockey, 1970b), and the processing of less relevant stimuli should be reduced (e.g., Callaway & Thompson, 1953; Hockey, 1970a; Nobata, Hakoda, & Ninose, 2010).

Consistent with this hypothesis, hearing an arousing word enhances one's ability to identify briefly presented words that follow, whereas seeing an arousing word impairs subsequent visual word identification (Zeelenberg & Bocanegra, 2010). When presented visually, the arousing stimuli are in direct competition for visual processing with the target words, whereas presenting the stimuli in two modalities reduces competition. When presented in the same modality, the competition between the arousing cue and the target word can be reduced by increasing the interval between them or by making the cue presentation extremely brief (Bocanegra & Zeelenberg, 2009a). Such manipulations can flip the effects of an emotional cue on subsequent word identification from impairment to enhancement—allowing a demonstration of both emotion-induced "blindness" and "hypervision" in the same study.

Taken together, these results conflict with theoretical accounts that emotional arousal narrows the attentional spotlight, leading to enhanced processing of spatially central and impaired processing of spatially peripheral information. Instead, they indicate that arousal biases attention toward goal-relevant or perceptually salient stimuli, regardless of their spatial location. Unfortunately, observing this attentional bias is complicated by the fact that the source of the arousal is often also a prioritized stimulus that competes for mental representation.

ABC in binocular rivalry

When two different images are separately presented to each eye, one does not experience a constant blurred combination of the two images. One's sensory experience instead oscillates between coherent representations of each image, a phenomenon known as binocular rivalry (Blake & Logothetis, 2002). The duration of time that either image occupies awareness can be controlled by focusing attention to particular features of the image (Chong & Blake, 2006) or its global configuration (J.F. Mitchell, Stoner, & Reynolds, 2004). Likewise, perceptual features, such as visual contrast, also influence the length of time a stimulus dominates awareness (Chong & Blake, 2006).

Emotional arousal influences this type of visual competition. During rivalrous trials, emotional pictures dominate awareness longer than do neutral pictures (Alpers & Pauli, 2006). Studies that control for low-level perceptual differences suggest that arousal is the factor driving this perceptual bias, as grating patterns paired with electric shock (Alpers, Ruhleder, Walz, Muhlberger, & Pauli, 2005) and schematic faces displaying negative expressions (Alpers & Gerdes, 2007) dominate awareness for longer than do equivalent nonarousing stimuli. Moreover, people are aware of grating patterns superimposed on faces expressing positive or negative expressions for longer than gratings superimposed on neutral faces (Bannerman, Milders, De Gelder, & Sahraie, 2008, Fig. 4). These effects can be observed for emotional stimuli of either valence, and a direct comparison of valence and arousal suggests that arousal is the emotional component driving this perceptual bias (Sheth & Pham, 2008).

How does ABC theory account for these effects? In the procedure depicted in Fig. 4, participants were told to focus only

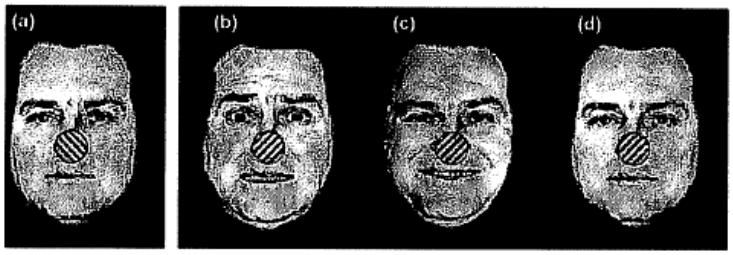

Fig. 4. Example stimuli used in Bannerman et al. (2008). Stimulus *(a)* was presented to one eye while stimulus *(b)*, *(c)*, or *(d)* was presented to the other eye.

on the gratings appearing in the white circle and to indicate the grating orientations. Thus, participants in that study had a top–down goal that gave the gratings priority. When focusing on a particular grating, if the background face evoked arousal (i.e., had an emotional expression), that increased the competitive advantage of that grating over the one being presented to the other eye.

Arousal makes it more difficult to keep track of multiple items

In the studies reviewed so far, stimuli either varied in priority or just one stimulus was the focus of attention at a time, allowing some information to benefit from ABC. However, having multiple high priority representations competing with each other can lead to overall suppression, as illustrated in Figure 1B. ABC theory predicts that arousal increases such mutual inhibitory effects. To maintain multiple representations in working memory, one must continuously cycle through them to ensure that each one remains active. When experiencing arousal, each time a stimulus representation is refreshed, there is an additional cost for competing stimuli. If all of the stimuli have equal priority, the result will be mutual inhibition and an overall decrement in working memory performance.

Consistent with this possibility, after viewing a slide show of negative arousing pictures, participants were worse at tracking the location of multiple moving dots than were participants who viewed a slide show of neutral pictures (Morelli & Burton, 2009). Likewise, when participants saw a sequence of four pictures, each appearing in a different location, their memory for the picture-location pairs over a short delay was worse if the four pictures were arousing (either positive or negative) than if they were neutral (Mather et al., 2006; K.J. Mitchell, Mather, Johnson, Raye, & Greene, 2006). These findings suggest that arousal makes it more difficult to maintain multiple representations of equal priority in working memory.

Brain mechanisms of ABC and top–down goals

As discussed earlier, a signature of biased competition is that the same neuron shows different response properties depending on how relevant the stimulus is to current goals. But how are top–down attentional goals represented? Much research suggests that a frontoparietal attention system comprised of parts of the intraparietal cortex and superior frontal cortex plays a key role in anticipating and implementing goal-directed selection both in attention (Corbetta & Shulman, 2002) and in memory retrieval (Cabeza, Ciaramelli, Olson, & Moscovitch, 2008).

As previously stated in this article, emotional arousal amplifies the effects of top–down attentional goals (Phelps et al., 2006; Schupp et al., 2007). One possibility is that the amygdala drives these arousal effects by enhancing the impact of top–down attentional goals in the frontoparietal network. Some initial evidence consistent with this possibility comes from an fMRI study in which participants were asked to detect a face and a scene presented near each other in a rapid stream of visual images (Lim, Padmala, & Pessoa, 2009). Some of the target faces and scenes were previously conditioned to be arousing and some to be neutral. As in previous studies (Anderson & Phelps, 2001; De Martino, Kalisch, Rees, & Dolan, 2009), participants were less likely to show an attentional blink (inability to detect the second target) when the second target was arousing than when it was not, even though in this study, the arousing stimuli were perceptually identical to the nonarousing stimuli. Furthermore, when participants correctly identified the targets, they showed greater amygdala activation for those arousing targets than for nonarousing targets. Most interesting, however, was that a trial-by-trial analysis of activity revealed that the influence of the amygdala on visual cortical responses was partially mediated by the medial frontal gyrus—a part of the frontoparietal attention network. Thus, the amygdala may modulate activity in the frontoparietal attention network to bias attention toward high priority stimuli (see also Mohanty, Egner, Monti, & Mesulam, 2009). This possibility fits with evidence that the amygdala activates when stimuli are potentially goal relevant (e.g., Cunningham, Raye, & Johnson, 2005; Sander, Grafman, & Zalla, 2003) or have high perceptual salience within an emotional context (Attar, Muller, Andersen, Buchel, & Rose, 2010).

In Lim et al.'s (2009) attentional blink paradigm, having targets be emotionally arousing enhanced participants' ability to carry out their goal of detecting the target. However, emotionally arousing stimuli can also distract people from their current

goal, as arousing stimuli attract attention themselves. In that case, one might expect the amygdala to still modulate activity in the frontoparietal attention network, but rather than enhancing goal-directed selection, the amygdala should diminish the impact of goal-directed selection by prioritizing the emotionally relevant distractor. Consistent with this possibility, when focusing on task-relevant stimuli in the presence of emotional distractors, amygdala activity increases while activity in the frontoparietal network decreases (Dolcos & McCarthy, 2006; D.G.V. Mitchell et al., 2008). These findings and those of Lim et al. suggest that the amygdala influences activity in the frontoparietal attention network—either increasing or decreasing how much attention is guided by top–down goals, which depends on whether attending to the source of the arousal is consistent with current task goals or not.

When arousing stimuli distract from current task goals, interactions between the amygdala and brain regions involved in resolving interference or conflict (such as the ACC or left inferior frontal cortex) may help to bias attention toward the emotionally arousing stimuli, or may help to counter the emotional distraction. In general, the ACC activates in situations involving conflict in information processing (Botvinick, Cohen, & Carter, 2004; Carter & van Veen, 2007). In one study, amygdala activity correlated with anterior and posterior cingulate cortices in the presence of distracting emotional images (D.G.V. Mitchell et al., 2008). Likewise, when masked fearful faces are used to orient attention to the spatial location of dot probes, amygdala activity was correlated with ACC activity and the amygdala–ACC correlation predicted attentional orienting to the masked fearful faces (Carlson, Reinke, & Habib, 2009). Thus, the ACC may help disengage attention from other stimuli and redirect it toward emotionally arousing stimuli.

The left inferior frontal cortex plays a key role in resolving interference (Aron, Robbins, & Poldrack, 2004; Jonides & Nee, 2006), and one study found that its activity correlated with the amygdala when distracting emotional stimuli were present (Dolcos, Kragel, Wang, & McCarthy, 2006). However, unlike the ACC activity in other studies, the inferior frontal cortex activity was associated with greater success in avoiding emotional distraction, rather than with orienting toward the emotional stimuli—thus, the left inferior frontal cortex may provide top–down modulation of the amygdala, reducing the degree to which distracting emotional stimuli dominate attention.

Summary of evidence for ABC in perception

The studies reviewed above reveal that emotional arousal leads to a "winner-takes-more" effect, in which already conspicuous stimuli gain priority while lower priority stimuli are further suppressed. For instance, hearing arousing sounds before viewing a set of letters makes the high contrast letters even more conspicuous than the low contrast letters (Sutherland & Mather, 2011). When one eye is shown an emotionally arousing image and the other is shown a neutral image, perception of the images alternates between them, but the emotionally arousing image tends to win the binocular rivalry competition for longer intervals (Alpers & Gerdes, 2007; Alpers & Pauli, 2006; Bannerman et al., 2008; Sheth & Pham, 2008).

Arousal also amplifies the effects of directed attention toward one target stimulus or location (Phelps et al., 2006; Schupp et al., 2007), consistent with the ABC hypothesis that arousal enhances the effects of top–down relevance. However, when there are multiple stimuli competing for dominance, arousal interferes with distributing attention across multiple stimuli (Morelli & Burton, 2009) and maintaining multiple representations in working memory (Mather et al., 2006; K.J. Mitchell et al., 2006). This arousal-based impairment when multiple stimuli are equally the target of attention is consistent with the idea that competition between adjacent strong representations leads to mutual interference (Fig. 1B).

The ABC effects described in this section are likely mediated by interactions between the amygdala and attention networks in the brain. For instance, there is evidence that the amygdala interacts with the frontoparietal attention network to enhance the priority of emotional stimuli that are the target of attentional goals (Lim et al., 2009). However, further research is needed to determine whether the amygdala helps to bias competition to favor nonarousing but high priority stimuli during episodes of arousal.

ABC During Encoding Shapes Memory

In this section, we turn to the emotional memory effects outlined in Table 1 and make the case that the first three of these effects and their apparent contradictions in the literature can be explained by ABC during encoding affecting what is later remembered.

Memory narrowing

In the 1950s, Callaway and colleagues introduced the idea that stress narrows attention, arguing that, "a narrowed focus of attention (i.e., a decreased influence of peripheral factors) seems related to some neurophysiological component of acute stress" (Callaway & Dembo, 1958, p. 74). Easterbrook's (1959) review of the literature argued that emotional arousal reduces the number of cues utilized in a task, contending that arousal and stress did not uniformly reduce cue utilization, but instead limited the use of peripheral (temporarily irrelevant) cues in favor of central (immediately relevant) cues. Subsequent researchers suggested that arousal also has opposite effects on memory for central and peripheral details, enhancing memory for central detail at the cost of peripheral detail (for reviews, see Christianson, 1992; Levine & Edelstein, 2009; Reisberg & Heuer, 2004). A classic example of arousal's effect on central versus peripheral details is the "weapon focus effect," in which the presence of a weapon reduces eyewitness identification of the perpetrator (Loftus, Loftus, & Messo, 1987; Steblay, 1992). Other examples consistent with memory narrowing come from studies examining memory for

emotionally arousing objects embedded within emotionally neutral scenes. When a negative arousing object, such as a snake or a demolished vehicle, is placed in front of a neutral background, such as a desert or a city street, people remember the arousing central objects better than the neutral objects (Kensinger, Garoff-Eaton, & Schacter, 2007; Kensinger, Gutchess, & Schacter, 2007; Waring & Kensinger, 2009). This emotional memory advantage creates a trade-off, however, as memory is worse for the background scenes behind the arousing objects than for background scenes behind neutral objects.

Emotionally provocative items, such as weapons and snakes, have high priority and also increase arousal. Thus, memory narrowing accounts and ABC theory both predict better memory for a central arousing stimulus and worse memory for surrounding information in comparison with situations in which the emotionally arousing stimulus is replaced by something neutral. However, ABC theory states that instead of specifically benefiting central information at the cost of peripheral information, emotional arousal enhances the representation of whatever has the highest priority (which often is central information, but not always) and impairs representations of stimuli that are lower priority. Thus, if a plot-irrelevant background stimulus were prioritized for some reason (such as moving in a perceptually salient way), participants experiencing heightened levels of arousal would have an additional benefit in memory for that stimulus.

Unfortunately, studies in the memory narrowing literature rarely separate the source of emotion and the focus of attention. Instead, researchers using memory narrowing studies typically induce emotional responses by introducing an arousing central stimulus, such as a wounded woman at the scene of an accident, and compare memory for details of the central stimulus with those of a less arousing central stimulus (e.g., Brown, 2003; Christianson, Loftus, Hoffman, & Loftus, 1991). Thus, the emotion-evoking stimulus and the central stimulus are confounded.

One study (Laney, Campbell, Heuer, & Reisberg, 2004) that attempted to separate the source of emotional arousal and the central target of the memory test had participants watch a nearly identical slide show manipulating emotion by the type of narrative that accompanied the slides. In the first experiment, participants exposed to the emotional narrative had better memory than did those who heard a neutral narrative, with the enhancement in memory being largest for the gist of the story line rather than for the specific contents of the slides. No significant memory impairment was observed in the emotional condition for central or peripheral visual details. In the second experiment, with a different set of slides and narratives, participants in the emotional group showed similar enhancements in memory for the narration gist, narration details, visual central details, and visual peripheral details. Thus, the findings argue against a memory narrowing account. However, it is hard to know how much the effects in this study were due to arousal and how much to interest level in the story line, as the mean heart rate did not differ significantly across the two conditions. Furthermore, much of the enhancement in memory in the emotion condition was for gist and details of the narrative, which was where the arousal was manipulated. Thus, even this study failed to thoroughly separate the emotion elicitor and the attentional focus.

Another study that reveals limitations of the narrowing account had participants view an arousing or nonarousing picture in a noncentral location on the screen (Mather, Gorlick, & Nesmith, 2009). One group viewed each picture with a "bystander" picture shown on the screen simultaneously, whereas the other group viewed the pictures placed on a wallpaper-like background. Arousing pictures significantly impaired memory for the backgrounds but not the bystander pictures. A narrowing account would predict similar impairments for both types of stimuli as they were both spatially peripheral to the arousing picture. In contrast, ABC theory predicts greater impairment for the background wallpaper than for the bystander picture, as the spatial arrangement would lead to greater baseline differences in priority between the background wallpaper and foreground arousing picture than between the two foreground pictures.

In our view, findings that support memory narrowing accounts are actually instances of arousal strengthening mental representations of high priority stimuli (see also Levine & Edelstein, 2009). Because of their perceptual salience and goal relevance, when emotional items evoke arousal, that arousal is likely to bias competition in their favor. Thus, when the arousing items are central, it may appear to be a memory narrowing effect. However, in general, arousal should increase the effects of competition between different representations, leading to winner-take-more and loser-take-less effects, regardless of whether the "winner" (the highest priority aspect of the experience) is spatially central or not.

Emotional arousal enhances memory for gist but not detail

Although the memory narrowing effects described in the previous section appear in many studies, distinguishing central and peripheral information is not sufficient to account for all the selective effects of emotional arousal on memory. For instance, inducing emotional arousal by interspersing a slide show with emotional pictures instead of neutral pictures increases the relative advantage in memory 24 hr later for the gist of the rest of the slide show compared with its details (Adolphs, Tranel, & Buchanan, 2005). This emotion enhancement effect for gist memory is not just an encoding effect, as it is also seen when participants first view and rate pictures and then watch a positive or negative arousing video instead of a neutral video (Liu, Graham, & Zorawski, 2008). A week later, participants who had viewed arousing videos had better gist memory for the preceding pictures but not better detail memory. Other studies have also found that inducing an emotional focus increases schema reliance in memory (Mather & Johnson, 2003; Mather, Johnson, & De Leonardis, 1999), that exercise-induced arousal increases the memory strength of stereotype consistent adjectives relative to neutral adjectives (Kim & Baron, 1988), and

that stress induced before learning lists of words increases false recognition of semantically related words (Payne, Nadel, Allen, Thomas, & Jacobs, 2002). Furthermore, whereas controls and patients with unilateral amygdala damage showed better memory for the gist of emotional pictures than the gist of neutral pictures, a patient with bilateral amygdala damage had poorer memory for the gist of emotional pictures than for the neutral pictures (Adolphs, Denburg, & Tranel, 2001).

The notion that arousal enhances gist but not detail is challenged, however, by findings that memory is better for the specific details of emotional objects (such as a hand grenade) than for the specific details of neutral objects (such as a basket; Kensinger, Garoff-Eaton, & Schacter, 2006, 2007). Thus, the idea that arousal enhances memory for gist but not detail does not hold up across all contexts; some other explanation is needed for the pattern of findings.

We argue that ABC theory can account for when arousal will enhance memory for gist and when it will enhance memory for details. In most events that have an overarching theme or narrative, the gist or schema is likely to be more salient and have more relevance than the details. In these types of events, increasing emotional arousal should increase the dominance of gist over details through ABC, which favors high priority information. Indeed, consistent with ABC theory, the gist–detail trade-off resulting from emotional stimuli has been shown to depend on what has highest prominence during encoding (Kensinger, Garoff-Eaton, & Schacter, 2007). In an initial experiment, when participants passively viewed a series of unrelated slides that each had a central item presented on a background, emotionally negative central items (such as a crashed car) yielded enhanced memory for both the specific details and the gist of that item but also decreased memory for the specific details of the background. Thus, this experiment demonstrated that emotional stimuli do not always lead to gist–detail trade-offs; emotion can enhance memory for details of the most prominent item in the scene (see also Kensinger et al., 2006). Furthermore, in a subsequent experiment in which participants were asked to describe the details of each scene such that an artist could reproduce them, central emotional items were associated with advantages for both gist and detail memory for background contexts as well as for the central items. These studies indicate that neither the gist–detail nor the central–periphery distinction can accurately predict what will be enhanced by emotional arousal. Instead, a more plausible account of these differences in memory requires distinguishing what has priority during encoding.

Arousal enhances within-object memory binding

A number of studies have found better memory for the color, location, or visual details of emotionally arousing items than nonarousing items (D'Argembeau & Van der Linden, 2004; Doerksen & Shimamura, 2001; Kensinger & Corkin, 2003; Kensinger, et al., 2006; MacKay & Ahmetzanov, 2005; MacKay et al., 2004; Mather et al., 2009; Mather & Nesmith, 2008; Mather & Sutherland, 2009; Nashiro & Mather, in press; but see Davidson, McFarland, & Glisky, 2006). In contrast, people do not usually have enhanced memory for the associations between emotionally arousing items and other items shown at the same time (Mather et al., 2009; Mather & Sutherland, 2009; Nashiro & Mather, in press; but see Guillet & Arndt, 2009).

Mather's (2007) object-based framework proposed that arousal-enhanced memory binding for within-object features occurs because (a) as outlined by Treisman (1999), perceptually binding features such as color and location to an object requires focused attention; (b) emotionally arousing stimuli attract focused attention; and (c) the ensuing perceptual binding advantage for emotionally arousing items is maintained during working memory, where emotionally arousing items dominate the competition for mental resources. Kensinger (2007, 2009) outlined a similar model in which negative emotional arousal (rather than emotional arousal more generally) enhances memory for the intrinsic details of negative events while impairing memory for extrinsic contextual details.

A challenge to these ideas is that one recent study found better memory for the association between two words when one of the words was emotionally arousing than when neither was arousing (Guillet & Arndt, 2009). Thus, the way that arousal affects memory binding cannot be predicted solely by whether the information to be bound is intrinsic to an item or is distinct.

According to ABC theory, arousal should enhance processing of whatever has highest priority and impair processing of lower priority information, regardless of whether its priority is due to bottom–up perceptual salience, or top–down attentional focus. The theory has implications for associative memory as well as for item memory. By winning the competition for processing resources, high priority items should garner not only better memory for their identity (e.g., ball) but also for their intrinsic features and location (e.g., red, rubber, in the corner). Thus, arousal may enhance associative memory for the features of high priority items. Furthermore, if the association between two items is high priority (e.g., it was Emily who threw the ball), that association should be further enhanced in memory by arousal.

ABC theory can account for findings that arousal typically enhances memory for the intrinsic features of arousing pictures or words (for a review, see Mather, 2007), as the arousal associated with those stimuli gives them higher priority. The theory can also explain why viewing an arousing item does not enhance memory for associations between that item and other competing nonarousing items (Mather et al., 2009) unless participants are asked to learn the associations at encoding—a task goal that should prioritize the item–item associations (Guillet & Arndt, 2009). In contrast, Mather's (2007) object-based framework cannot account for situations in which arousal enhances memory for item–item associations.

In their "binding hypothesis," MacKay and colleagues argue that emotional reactions enhance binding of the source of the emotion to salient aspects of the context (Hadley & MacKay, 2006; MacKay & Ahmetzanov, 2005). Although this

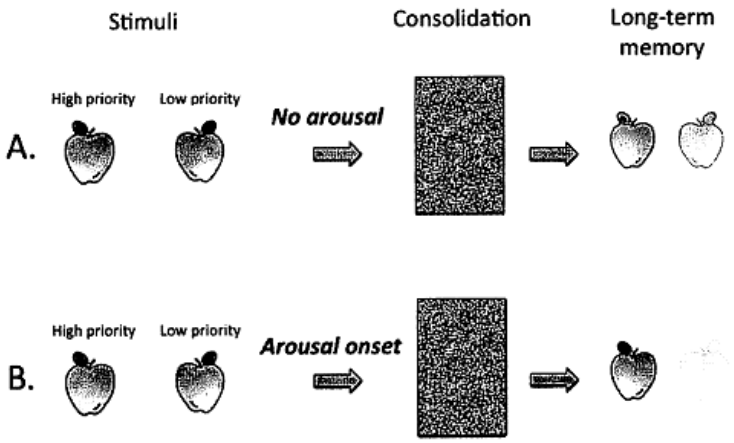

Fig. 5. A schematic of how arousal-biased competition influences memory consolidation. A: In an initial low-arousal encounter with two apples, one has higher priority than the other for either bottom–up or top–down reasons. After the passage of time and memory consolidation, memory representations for both apples have faded, but the initially higher priority apple has a stronger representation that is more easily and vividly retrieved than that of the lower priority apple. B: Experiencing arousal while processing two stimuli in competition with each other for mental resources leads to even more enhancement in memory consolidation for the "winner" and impairment for the "loser," creating a "winner-take-more" effect in memory consolidation.

binding hypothesis can account for Guillet and Arndt's findings (insofar as the other item is a salient part of the context), it focuses only on binding information to the emotional item and does not make predictions about binding for other high priority information.

ABC theory goes a step further by predicting that arousal will enhance binding for high priority information regardless of whether that information is emotional or not. Consistent with this prediction, participants exposed to a constant loud noise during their experiment session showed stronger effects of top–down priority (Smith, 1982). Specifically, if told to prioritize memory for the word locations over the word order, the aroused subjects showed better memory for the location and slightly worse memory for the order than did control (soft noise) participants. If told to prioritize memory for the word order, the aroused participants showed better memory for word order and slightly worse memory for the word location than did control participants who were given the same encoding instructions but were not exposed to the arousing loud noise.

Thus, consistent with ABC theory, arousal enhances memory binding for high priority information, regardless of whether the prioritized information is arousing or not. Moreover, arousal-enhanced memory binding is not limited to intrinsic features of single items, but can enhance binding (associations) of two separate items in memory as well, assuming the association between the two items has high priority when arousal is experienced.

ABC in Memory Consolidation

So far, we have focused on how arousal affects initial perception and encoding of information, arguing that arousal amplifies competition between high and low priority stimuli. In this section, we suggest that this ABC effect continues after initial perception, amplifying memory consolidation for high priority stimuli while decreasing memory consolidation for low priority stimuli (Fig. 5). Furthermore, we extend this hypothesis to stimuli experienced prior to the onset of arousal or stress, arguing that arousal or stress amplifies preexisting priority differences among stimuli with currently active mental representations. These mechanisms can account for the two remaining arousal effects described in Table 1.

Arousal creates retrograde amnesia

When an emotional picture or word is an "oddball" in a list—in other words, it is different from all the rest of the items—it will typically impair memory for stimuli preceding or following it more than nonemotional oddballs do (Bornstein, Liebel, & Scarberry, 1998; Detterman & Ellis, 1972; Ellis, Detterman, Runcie, McCarver, & Craig, 1971; Erdelyi & Blumenth, 1973; Hadley & MacKay, 2006; Hurlemann et al., 2005; Knight & Mather, 2009; MacKay et al., 2004; Miu, Heilman, Opre, & Miclea, 2005; Runcie & Obannon, 1977; Schmidt, 2002; Strange, Hurlemann, & Dolan, 2003). However, when participants were asked to study one neutral face and were shown

either an emotional or a neutral picture immediately afterwards, a week later, they remembered the faces that appeared before the emotional pictures *better* than those that appeared before the neutral pictures (Anderson, Wais, & Gabrieli, 2006). This raises the question of how arousal can sometimes enhance and sometimes impair memory for preceding neutral stimuli.

In oddball-type studies, participants are typically presented with many lists of perceptually similar neutral items, with one distinctive oddball in each list. Thus, items preceding the oddball would be low priority relative to the oddball, which was quite distinctive and memorable. Having the oddball item be arousing further suppresses the low priority nearby neutral items.

However, if a neutral item could be made to be high priority, then following up with an arousing stimulus should enhance later memory for the neutral item. Indeed, emotional pictures did enhance memory for preceding pictures when, on each trial, participants were shown one neutral face followed by a modulator emotional or neutral picture (Anderson et al., 2006). The participants' task was to indicate whether they would remember the face later or not, which should have given the face priority. Furthermore, the face was the only stimulus shown before the modulator picture, reducing competition among preceding items compared with the experiments with oddballs embedded in lists of neutral items.

These findings across different studies suggest the highest priority stimuli prior to the onset of emotional arousal or stress will be enhanced in long-term memory, whereas lower priority stimuli prior to the onset of arousal or stress will be suppressed. Results from a study showing both retrograde impairment and enhancement in the same paradigm support this hypothesis (Knight & Mather, 2009). This study tested a number of potential factors that might account for the conflicting effects of emotional stimuli on memory for preceding items and found that the key factors were both the delay and the amount of encoding effort directed toward an item. Retrograde amnesia effects were most likely when there were larger sets of neutral items appearing before each emotional item and when memory was tested immediately. In contrast, retrograde enhancement effects only appeared after a longer delay (one week rather than within the same session) and only for preceding items that participants either were trying to learn or for those that they had successfully retrieved on an immediate test. Thus, retrograde enhancement for items seen before emotionally arousing items depends both on the initial priority of the neutral preceding item and on the passage of time.

Arousal enhances consolidation for emotional items

The idea that arousal experienced shortly after encoding new information will enhance or impair memory consolidation depending on the information priority can also help explain some other contradictory findings in the literature. Some studies find that postencoding arousal enhances memory for emotional items but impairs or does not affect memory for neutral items, when emotional and neutral items are intermixed on a study list (Buchanan & Lovallo, 2001; Cahill, Gorski, & Le, 2003; Liu et al., 2008; Smeets, Otgaar, Candel, & Wolf, 2008; see also Abercrombie, Speck, & Monticelli, 2006; Segal & Cahill, 2009). However, when participants were asked to memorize only neutral information and were then given an arousal induction or shown arousing stimuli, they showed enhanced memory later for the neutral information (Anderson et al., 2006; Andreano & Cahill, 2006; Knight & Mather, 2009; Nielson & Powless, 2007; Nielson, Yee, & Erickson, 2005; see also Maheu, Joober, Beaulieu, & Lupien, 2004).

ABC theory suggests that these mixed findings about whether postlearning arousal enhances consolidation of neutral information arise from differences in stimulus priority during initial encoding. Specifically, for the studies using emotional–neutral mixed slide shows (Buchanan & Lovallo, 2001; Cahill et al., 2003; Liu et al., 2008), ABC theory suggests that postencoding stress enhances memory for arousing stimuli because these stimuli are more conspicuous than the competing neutral stimuli. In other studies that ask participants to learn emotionally neutral material, the highest priority information should be found among the neutral to-be-learned material due to its top–down goal relevance and should therefore gain from ABC.[3] In contrast, goal-irrelevant information from the experimental context should be less likely to be remembered. In other words, the marker the brain uses to have postencoding arousal or stress selectively enhance certain information from an event is priority (Fig. 5).

Consistent with this argument, there is evidence from the animal literature that postlearning induction of epinephrine (e.g., Jurado-Berbel, Costa-Miserachs, Torras-Garcia, Coll-Andreu, & Portell-Cortes, 2010) or norepinephrine (Roozendaal, Castello, Vedana, Barsegyan, & McGaugh, 2008) can enhance memory for neutral information that was the focus of attention shortly before the stress hormone induction. Furthermore, Roozendaal et al. (2008) infused norepinephrine or the β-adrenoceptor antagonist propranolol directly into the basolateral amygdala after rats were presented with two versions of a novel object, linking these effects to the amygdala. They found dose-dependent memory enhancement for the object 24 hr later in the norepinephrine condition and dose-dependent memory impairment in the propranolol condition. Thus, noradrenergic activation of the basolateral amygdala modulates long-term consolidation of memory for novel information that was just learned, even when that information was not inherently emotional.

A recent study with rats demonstrates increased neural representation of stimuli perceived during amygdala activation (Chavez, McGaugh, & Weinberger, 2009). In this experiment, rats under general anesthesia heard tones. Initially, the researchers used electrodes placed in the primary auditory cortex to find out which tone frequency produced the greatest neuronal activity for particular receptive fields. They then selected a different tone and played that tone 100 times overlapping with brief stimulation of the basolateral amygdala. If the amygdala stimulation occurred 1 s after tone onset, there was a shift in the nature of the receptive field such that it shifted gradually

over the next 75 min to become most responsive to the new tone rather than to its original preferred tone. In contrast, if the amygdala stimulation was a little later after the tone onset (1.6 s), there was little evidence of a shift in what tones were represented by that receptive field. This suggests that, at least under anesthesia, amygdala activation must occur very closely in time to the auditory stimulus in order to modulate its representation. More generally, these findings suggest that the basolateral amygdala modulates memory consolidation by shifting the tuning of neurons to represent sensory memories for salient events that occurred during amygdala activation. This may be one way in which arousal biases neural representation in favor of prominent events occurring close in time to an increase in arousal.

From the perspective of our ABC theory, whether or not arousal-induced amygdala activation enhances long-term consolidation of information encoded prior to or during arousal onset depends on each stimulus' priority during encoding. When the stimulus itself is emotionally arousing, it gains priority over other nonemotional stimuli. Thus, ABC will lead to enhanced memory consolidation of emotional stimuli on intermixed lists. However, ABC mechanisms can also enhance memory for high priority nonemotional stimuli. Future studies should manipulate the bottom–up perceptual salience or top–down goal relevance of neutral material encoded prior to evoked emotional arousal or pharmacological manipulations of epinephrine and cortisol, as this would allow a direct test of ABC theory in the domain of long-term memory consolidation.

Arousal Versus Valence Effects

In this article, we have argued that arousal stimulates the amygdala to modulate sensory processing, frontoparietal attention networks, and memory consolidation of high priority information in ways that increase the selectivity of attention and memory for arousing experiences. But what about valence, the other primary dimension of emotion? How might it affect biased competition?

As arousal activates the amygdala regardless of whether it is elicited by positive or negative stimuli (e.g., Anderson et al., 2003; Cunningham, Raye, & Johnson, 2004; Hamann, Ely, Hoffman, & Kilts, 2002; Mather et al., 2004), it makes sense that positive and negative sources of arousal would have similar effects on how the amygdala biases attention. Indeed, previous studies suggest that arousal is more of a critical factor than valence in biasing competition. Both positive and negative arousing stimuli affect attentional selectivity—for instance, in binocular rivalry (Sheth & Pham, 2008) and in the attentional blink (Anderson, 2005; Keil & Ihssen, 2004). Likewise, both erotica and mutilation pictures amplify the effects of attention as measured by ERP (Schupp et al., 2007). Positive and negative arousing pictures yield similar enhancements in location memory binding (Mather & Nesmith, 2008; Mather & Sutherland, 2009). And negative and positive arousal also have similar effects on long-term memory consolidation; watching either a positive or negative arousing video clip enhances consolidation of high priority items encoded just before the video (Liu, et al., 2008; Nielson & Powless, 2007).

However, even if arousal evoked by positive or negative stimuli affects biased competition in the same manner, valence may influence other aspects of cognitive processing differently. One intriguing possibility is that negative emotion impairs semantic processing but enhances perceptual processing, whereas the reverse is the case for positive emotion (for a review, see Kensinger, 2009). Neuroimaging studies have found that negative items that are later remembered recruit brain regions involved in sensory processing more than positive items that are later remembered (Kensinger & Schacter, 2008; Mickley & Kensinger, 2008), whereas the encoding of positive items is associated with greater activation in regions associated with semantic or conceptual processing (Kensinger & Schacter, 2008). A behavioral study in which participants were shown a picture on each trial, followed by a semantic or perceptual judgment about an object, found that, compared with positive pictures, negative pictures slowed subsequent reaction times on semantic tasks but not on perceptual tasks (Sakaki, Gorlick, & Mather, 2010). Negative mood inductions also impair semantic priming compared with positive mood inductions or baseline (Storbeck & Clore, 2008).

In addition, others have found evidence that exposure to positive stimuli broadens cognitive processes, including one's scope of attention (Fredrickson & Branigan, 2005), which results in increased perceptual processing of task-irrelevant stimuli (Rowe, Hirsh, & Anderson, 2007). After viewing a series of positive images, viewing task-irrelevant houses in the periphery of one's visual field increased responses in the parahippocampal place area, whereas the opposite effect was observed upon exposure to negative pictures (Schmitz, De Rosa, & Anderson, 2009). Increased processing of task-irrelevant information during positive arousal would conflict with the predictions made by ABC. However, it is important to note that these studies did not use highly arousing stimuli. The positive and negative stimuli used by Rowe et al. differed from neutral stimuli only in terms of valence, not arousal. Similarly, Schmitz et al. used positive and negative stimuli that varied widely in terms of arousal, and they specifically excluded high arousing stimuli such as mutilation and erotica. ABC theory would not predict differences between neutral and emotional stimuli when they evoke similar arousal responses.

These studies suggest that positive and negative affect may have opposite effects on selective attention at low levels of arousal. However, when primed with high-approach-motivated positive affect (via a cue indicating a potential reward for correct performance or via a picture of an appetitive picture), participants showed enhanced memory for words subsequently shown in the central task-relevant location and either no enhancement or impairment for words shown in peripheral task-irrelevant locations (Gable & Harmon-Jones, 2010b). Positive stimuli cueing high approach motivation tend to have higher arousal than low-approach-motivation positive stimuli (Gable & Harmon-Jones, 2010a), and thus high arousal positive

stimuli seem to enhance memory for stimuli presented in the central task-relevant location but not memory for peripheral stimuli—a finding that is consistent with ABC predictions.

The studies outlined in this section suggest that negative and positive affect have opposite effects on perceptual and semantic processing. Furthermore, at low levels of arousal, positive and negative affect may influence perceptual processing differently. These effects are also likely to influence memory and may interact with ABC effects.

Conclusions

Psychologists have long been fascinated by how emotional arousal affects perception, attention, and memory. For instance, in 1890, William James wrote, "An impression may be so exciting emotionally as almost to leave a *scar* upon the cerebral tissues" (James, 1890, p. 670). Although a mere 10 pages later, when discussing forgetting, James noted that, "Selection is the very keel on which our mental ship is built," he did not link emotion and selection processes in memory. Most researchers followed James' lead, focusing on enhanced processing of emotionally arousing information. In recent years, research into the general mechanisms of arousal and memory has focused on the key role of the amygdala in enhancing perception and memory of emotionally arousing stimuli (for reviews, see LaBar & Cabeza, 2006; McGaugh, 2004; Murty, Ritchey, Adcock, & LaBar, 2010; Payne & Kensinger, 2010; Phelps, 2004). However, as reviewed in this article and summarized in Table 1, enhanced memory for arousing information is only part of the pattern—there is also abundant evidence for arousal's selective effects in memory.

The ABC theory outlined here involves some simple mechanisms that can account for a broad range of arousal-induced selectivity effects in memory, even findings that initially appear contradictory such as those in the middle and right-hand columns of Table 1. ABC theory proposes that when initially processing information, arousal influences competition between different stimuli for mental resources, increasing processing of high priority stimuli and decreasing processing of low priority stimuli. Furthermore, ABC theory posits that arousal experienced during or just after an event biases memory consolidation in favor of high priority information from the event and against low priority information from that event. Priority is determined by bottom–up perceptual salience and top–down relevance.

Thus, arousal should enhance processing and consolidation of high priority information, regardless of whether the information has priority because of its bottom–up attention grabbing nature or because of top–down goals such as the desire to remember it later. This winner-take-more effect may be adaptive. Arousal is likely to be associated with challenging, important, or threatening events, for which fast and focused responding is critical. Enhanced processing of salient, surprising, or goal-relevant stimuli should improve performance under such circumstances. Later, remembering the high priority information from the event could improve future strategies for dealing with similar situations. But the increased advantage of high priority information comes at the expense of low priority information that garners even fewer neural resources under arousal than it would otherwise.

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Notes

1. The studies described used low spatial frequency contrast gratings (i.e., with wide stripes). However, a recent study suggests that arousal does not enhance detection of high-spatial-frequency contrast gratings (Bocanegra & Zeelenberg, 2009b). In fact, exposure to fear faces impaired tilt direction discrimination of subsequent high-spatial-frequency contrast gratings while enhancing tilt detection for low-spatial-frequency gratings. The authors suggested that the differences stem from the amygdala having more projections to the magnocellular visual pathways than to the parvocellular visual pathways, leading emotion to create a trade-off between magnocellular and parvocellular pathway information. Magnocellular channels process movement, small differences in brightness, and low spatial frequency information, whereas parvocellular channels process color, form, and the fine details conveyed by high spatial frequencies (Livingstone & Hubel, 1988). More work is needed to see if arousal generally enhances contrast within magnocellular pathways but not within parvocellular pathways or if there is some other factor driving the difference between high and low frequencies.
2. In Cornsweet's study, the peripheral light cues predicted the onset of a central light that required a fast keypress; participants' reaction times to the central lights were increased more by the peripheral warning cues in the stress condition.
3. In contrast with other studies, Henckens, Hermans, Pu, Joels, and Fernandez (2009) found no difference in memory for arousing and neutral pictures when encoded in between the presentation of stress-inducing or neutral video clips. The content of the pictures overlapped with the contents in the film, so as to construct a 'continuous and coherent stressful episode.' This may have attenuated any biased competition advantage for arousing pictures, as the neutral pictures may have been equally the focus of attention because of their conceptual links with the arousing pictures and the stress-inducing movie clips.

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Memory and the Operational Witness: Police officer recall of firearms encounters as a function of active response role

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Abstract

Investigations following critical events often depend on accurate and detailed recall accounts from operational witnesses (e.g., law enforcement officers, military personnel, emergency responders). However, the challenging, and often stressful, nature of such events, together with the cognitive demands imposed on operational witnesses as a function of their active role, may impair subsequent recall. We compared the recall performance of operational *active* witnesses with that of non-operational *observer* witnesses for a challenging simulated scenario involving an armed perpetrator. Seventy-six police officers participated in pairs. In each pair, one officer (active witness) was armed and instructed to respond to the scenario as they would in an operational setting, while the other (observer witness) was instructed to simply observe the scenario. All officers then completed free reports and responded to closed questions. Active witnesses showed a pattern of heart rate activity consistent with an increased stress response during the event, and subsequently reported significantly fewer correct details about the critical phase of the scenario. The level of stress experienced during the scenario mediated the effect of officer role on memory performance. Across the sample, almost one-fifth of officers reported that the perpetrator had pointed a weapon at them although the weapon had remained in the waistband of the perpetrator's trousers throughout the critical phase of the encounter. These findings highlight the need for investigator awareness of both the impact of operational involvement and stress-related effects on memory for ostensibly salient details, and reflect the importance of careful and ethical information elicitation techniques.

Law enforcement officers, military personnel, and others in civil or emergency response occupations are frequently involved in dynamic, challenging incidents. Depending on their particular operational mandate, these 'operational witnesses' may need to act to preserve life, protect citizens, neutralize threats, initiate recovery or engage in some combination of related activities to resolve an incident. Accurate and detailed accounts of the incident, and information about the operational witness's own activities and that of colleagues, may be important for subsequent investigations and the eventual delivery of justice (Alpert, 2009). Nowhere is this more critical than in the case of shootings by armed police officers who are authorized by the State to discharge a weapon in the course of their duty to protect and avert imminent threats to life (ACPO, 2011; Armed Policing Authorised Professional Practice, 2013). The current research examined the effects of active involvement on eyewitness recall memory - specifically, we compared the recall performance of operationally active witnesses responding to a (simulated) threatening incident with that of non-operational witnesses, or bystanders, to the same event; hereafter referred to as active and observer witnesses respectively.

Recent high profile cases, such as the shooting of Mark Duggan in the UK, serve to highlight tensions in the investigation of armed incidents. Duggan was shot by an armed officer in London. A Public Inquest, conducted between September 2013 and January 2014 concluded that the shooting had constituted a lawful killing (see http://dugganinquest.independent.gov.uk/latest-news.htm). However, in the course of both the investigation and inquest, questions were raised with respect to officers' accounts of the incident, and perceived inconsistencies in the statement provided by the officer who discharged his weapon were widely reported in the media. Perhaps unsurprisingly, skepticism over the accounts provided by officers in the aftermath of fatal shootings is well documented both in the UK and internationally, and generally focuses on the potential for police collusion

or corruption (Braidwood, 2012; Heaton-Armstrong & Wolchover, 1993; Heaton-Armstrong & Wolchover, 2009; see also Hope, Gabbert & Fraser, 2013). While the deliberate fabrication of evidence lies beyond the scope of the current article, there is a less controversial explanation for at least some of the apparent inconsistencies and inaccuracies in the "honestly held" accounts provided by operational responders in the aftermath of stressful incidents. The common lay belief that memory operates like a video-recorder - often subscribed to by investigators, legal experts and potential jury members - is woefully inaccurate (Simons & Chabris, 2011; see also Benton, Ross, Bradshaw, Thomas & Bradshaw, 2006). Memory is a dynamic and reconstructive process, susceptible to error and distortion (Schacter, 1999). It is well documented, in over forty years of research, that eyewitness memory is fallible – even under optimal encoding conditions (Conway, 2012).

The recall of operationally active witnesses may suffer additional performance decrements due to their role in challenging response contexts; for instance, as a result of increased cognitive demands associated with response generation or decision-making. Understanding how memory performs under such conditions is important for a number of reasons. First, there is a dearth of research examining memory performance under realistic operational conditions (simulated or otherwise). Second, it is important that procedures and policies relating to the treatment of operational witnesses by independent investigators or other agencies are (a) well-informed with respect to the malleability of memory and (b) appreciate the necessity for careful and ethical memory elicitation practices. Third, it is critical that practitioners in the legal system, whether lawyers, prosecutors or judges, are cognizant of the potential for naturally-occurring memory errors, gaps and inconsistencies among all witnesses but particularly operational witnesses, such as armed officers, who are often expected to provide detailed and accurate accounts of challenging incidents they were immersed in.

In light of these concerns, we examined the memory performance of witnesses with operational duties (i.e., police officers actively responding to a simulated incident) with that of witnesses who had not been operationally deployed (i.e., observers). We also explored the effect of schema-driven expectation in operational contexts on memory error.

Stress, Arousal and Memory Performance

Armed officers regularly find themselves in unpredictable, dangerous environments and may experience varying degrees of emotional arousal and/or stress response (Meyerhoff et al., 2004). Research on the effect of arousal on cognitive processes in applied training settings reveals the cognitive and memory difficulties experienced in high stress environments. For example, Morgan and colleagues (2004) tested the memories of soldier participants in an intensive survival school training exercise who had been exposed to high levels of interrogation stress, including physical confrontation. Memory performance, in terms of the recognition of a target individual who had physically confronted and threatened them for over 30 minutes, was impaired following high stress (versus low stress) interrogations. More recently in a study involving 861 soldiers in a similar survival training simulation, Morgan, Southwick, Steffian, Hazlett, and Loftus (2013) observed that memories for stressful events, like memories for more mundane events, are susceptible to misleading post-event information. Challenging field environments are also associated with significant impairment in selective and sustained attention (Leach & Ansell, 2008) and reduced working memory capacity (Leach & Griffith, 2008). Focusing on the performance of police officers in simulated operational settings, Hope et al. (2012) examined the effects of physiological stress, as a function of exertion, on recall and recognition and found that police officers who had been exerted prior to and during encoding reported significantly fewer correct details about an encounter, and were significantly less likely than non-exerted officers to identify an encountered target individual.

The precise mechanisms underpinning memory impairment as a result of stress and arousal are difficult to directly delineate in the applied context. A large body of literature confirms that emotionally arousing events are remembered better than neutral events (e.g. Payne et al., 2006) with neurobiological research, in particular, suggesting that stress hormones can enhance memory consolidation (McGaugh, 2000, Roozendal, 2000; see also McGaugh, 2013). Researchers have also speculated that attentional narrowing under arousal underpins this recall advantage such that memory for central or important stimuli is enhanced (on the grounds that such items "capture attention") while memory for peripheral items is impaired (Safer, Christianson, Autry, & Osterlund, 1998; see also Easterbrook, 1959). However, there are a number of problems applying this rather simplistic account to the complex interaction between stress and arousal on memory in applied contexts. First, the detrimental effects of high levels of stress experienced in naturalistic settings have been well-documented (e.g. Morgan et al., 2004, 2013). In fact, in their meta-analysis, Deffenbacher et al. (2004) identify what they describe as a "catastrophic" decline in memory performance at higher stress levels. As such, the effect of arousal on memory performance reflects an inverted U-shaped curve with memory for events best when stress levels are moderate (Morley & Farr, 2012). Thus, while arousal may activate the amygdala (Adolphs, Tranel, & Buchanan, 2005; Phelps, 2006), higher levels of stress work to disrupt hippocampus function, impairing memory for sensory detail and visuospatial working memory (Shackman et al., 2006; for an extended version of this argument see Davis & Loftus, 2009). Furthermore, pharmacological research observes that stress hormones in the form of glococoricoids and catecholamines (adrenaline/nor-adrenaline), naturally released during stress (De Kloet et al., 1998), have variable effects on memory, depending on a number of modulatory factors (Lupien & Lepage, 2001; Wolf, 2003). In particular, the release of cortisol (or its administration in placebo-controlled pharmacological studies) is associated with impaired

memory retrieval (DeQuervain et al., 2000; Kuhlmann, Piel, & Wolf, 2005; Wolf et al., 2001). Similarly, in a sample of Special Forces candidates evaluated in the course of an intense naturalistic stressor, high levels of cortisol secretion were associated with impaired cognitive performance relative to a control group (Taverniers, Taylor & Smeets, 2013).

A second problem with "attentional narrowing" accounts, as noted by Davis and Loftus (2009), is that emotional arousal may not narrow attention in all cases, and certainly not to predictable stimuli. In fact, stress impairs executive function (Schoofs, Wolf, & Smeets, 2009), including the ability to control attention or where it is directed (Banks, Tartar & Welhaf, 2014). Laboratory work demonstrating supposed attentional narrowing typically uses relatively uncomplicated or unambiguous stimuli (e.g., the deliberate presentation of a single weapon in much of the so-called weapon focus literature) in a third-hand presentation format (e.g., video or slides). In real life situations, there are likely to be many conflicting draws on attention as a function of (a) a more complicated interactive scene and (b) the need to respond to an incident, which may further deplete cognitive resources. Taken together, these factors make it difficult to predict what will be remembered from stressful naturalistic events. Thus, the first aim of the current study was to examine the effects of arousal, experienced in a challenging yet controlled event, on officer recall as a function of response role.

Attentional load, training and expectations

Both operationally active and lay (or civilian) witnesses' memories for an incident may be impaired as a consequence of high stress levels during encoding. However, active witnesses have the additional task of deriving an appropriate response strategy (in light of various and potentially transient contextual factors, and taking into account their own safety and that of others in the vicinity), planning the effective execution of that strategy and then

taking action accordingly (see Eyre & Alison, 2007). Obviously, an important contextual factor in minimizing the cognitive 'drain' of such activities should be the effective training of operationally active witnesses such that response options are fluently available (e.g., recognition-primed decision-making, Klein, 1998; see also Clark, 2008 and Healy, Kole & Bourne, 2014). However, by its nature, training might set expectations about the likely outcomes of particular scenarios. According to Neisser's (1976) notion of the "perceptual cycle", individuals perceive, interpret and revise their understanding of information using both top-down and bottom-up processes. Certain stimulus properties elicit an attentional response and, inevitably, expectations derived from existing schemas guide further interpretation and recollection (e.g., Tuckey & Brewer, 2003; see also Most, Scholl, Clifford & Simons, 2005). For example, when specific schemas are activated, visual attention is likely to be directed towards schema-relevant items (Eberhardt, Goff, Purdie & Davis, 2004). Evaluating an emerging situation and responding appropriately are critical police activities, particularly for high stakes incidents. However, these activities will likely take place under conditions of time pressure, depleted cognitive resources and additional cognitive load – conditions under which such evaluations, and subsequent recollection, may be particularly vulnerable to schema-driven or expectation-based errors (e.g. Brewer & Tuckey, 2003; Kleider, Pezdek, Goldinger, & Kirk, 2008; Sherman & Bessenoff, 1999; see Betts & Hinsz, 2013). If, under such circumstances, the available schema posits that Action X is usually followed by Action Y, then "interpretations or classifications made on the basis of emotion- or expectation-weakened identification criteria, unchecked by disconfirming evidence, enter long-term memory uncorrected and become the basis of distorted witness reports" (Davis & Loftus, 2009, p.182). Thus, the second aim of the current study was to examine whether active witnesses, like other professionals in high reliability roles (e.g., Plant, 2012), may be vulnerable to expectation-based errors that impact the accuracy of their subsequent accounts.

Current Study

Our research was motivated by two main research questions. First, we examined whether there were differences in the accounts provided by operational (active) and non-operational (observer) witnesses where both had been exposed to the same incident. To achieve this we put pairs of police officers into an immersive and stressful augmented reality simulated scenario where one officer was instructed to respond as they would usually in the course of their duty (i.e., an active operational witness) while the other was instructed to simply observe the scenario. To our knowledge, this is the first study to adopt a methodology of this kind to examine the effects of active role involvement in an eyewitness context. We predicted that officers allocated to the active response role would show an increased physiological response in the scenario, reflecting by proxy, increased stress as a function of their active response role. On the grounds of this increased arousal, and consistent with the theoretical accounts outlined above, we predicted that the quality and quantity of free recall reported by the active response officers would be impaired relative to the observers.

In addition to the free recall task, both witnesses were asked a series of detailed closed questions. These questions were included to contribute data and inform current practice and policy in the investigation of shooting incidents. In a number of recent cases, after providing written statements, operational witnesses have been asked to respond to long lists of additional detailed closed questions (see Dodd & Travis, 2014). Research on investigative interviewing has long documented the problems associated with closed question interviewing approaches (cf. open questions), not least the dangers of leading, closed questions (e.g. Sharman & Powell, 2012). Current 'gold standard' interview techniques, such as the Cognitive Interview (Fisher & Geiselman, 1992) and the National Institute for Child Health and Development Protocol (NICHD; Lamb, Orbach, Hershkowitz, Esplin, & Horowitz, 2007) endorse the use of open-ended questions with compliant witnesses (for overview, see Vrij,

Hope, & Fisher, 2014). In the current study, participants were exposed to an extended set of closed questions modelled on the question style often adopted by investigators (see *Method*). In addition to documenting accuracy rates for such questions, we were particularly interested in the recall performance of active witnesses (relative to their observing co-witnesses) on questions pertaining to use and location of the target's weapon as such questions are, unsurprisingly, a central focus of investigations following police shootings. Specifically, we predicted that additional demands on the resources of operational witnesses in conjunction with higher arousal and stress levels, both likely to occur when police officers were required to discharge (or consider discharging) their own weapon, would impair recall for such information.

Our second independent research question concerned the possible effect of expectations as they relate to memory performance under challenging operational conditions. Deliberately, the scenario was designed to trigger schema-driven expectations regarding the likely action of the perpetrator. In the final sequence of the scenario, the perpetrator who was at this point known to be armed, turned quickly to face the officers, throwing out his hands in front of him. However, the weapon (a gun) remained in the waistband of his trousers. In light of the memory deficits reported in previous research (e.g., Morgan et al., 2013) and well-documented effects of schema-reliance (e.g. Kruglanski & Freund, 1983; Tuckey & Brewer, 2003), we predicted that memory reports provided by officers in the Active (cf. Observer) condition may be particularly vulnerable to the expectation-based error that the perpetrator would point the weapon at them. For the current study, it should be noted that our research questions were entirely focused on post-event recollection by officers and not behavioral outcomes, such as shoot/no-shoot decisions which are explored elsewhere (e.g. Akinola & Mendes, 2012, Nieuwenhuys, Savelsbergh & Oudejans, 2012).

Method

Participants

Eighty-seven serving Canadian law enforcement officers affiliated to a metropolitan force were recruited. Due to technical difficulties, incomplete data or single participant sessions (due to unavoidable no-shows), the final sample comprised 76 participants. Participants (64 males) were aged 22 to 59 years of age ($M = 37$ years, $SD = 7.99$). Most of the sample was at Constable rank (94%) with the remainder at Detective (3%) and Sergeant (3%) rank. Recruited officers represented a range of experience with an average length of service of 147.75 months of service ($M = 12.31$ years; $SD = 89.47$ months).

The purpose or nature of the study was not revealed in advance - participants were led to believe that they were taking part in research related to officer response. Officer participation in the research was voluntary and took place during work hours at pre-arranged times with the full agreement of shift supervisors. Although the research was organized in collaboration with the training division of the force, test sessions did not constitute formal training events. Officers were not paid for their participation and received no work-related rewards for taking part. In addition to adhering to standard ethical principles and considerations, detailed Informed Consent procedures assured officers that their individual professional performance was not being assessed and re-iterated confidentiality procedures.

Design

Officers were randomly assigned to either the 'Active Officer' or 'Observer Officer' condition during the encoding phase. Conditions were paired such that each 'Active Officer' viewed the scenario with an 'Observer Officer'. All participants completed the same test materials. The experimental data were collected over a five-day period. In a typical test day, eight pairs took part in live scenarios.

Materials

Briefing video. Prior to deployment into the main scenario, all officers viewed a short 'briefing' video that depicted the initial hostage-taking incident. It showed students taking part in a classroom-based seminar with their professor and was filmed on a cell phone (as if from the perspective of one of the students). The perpetrator (an apparently disgruntled student) entered the classroom and engaged the professor in a discussion about poor grades. The perpetrator became increasingly agitated, drew a knife from his pocket, and took the professor and a student hostage. Toward the end of the video, the other students are seen rushing from the room, initiating calls to the police. The film, recorded using an iPhone, lasted 2 mins 10 secs and was of high quality with clear audio.

Experimental Scenario. The scenario was developed in the course of extensive discussion with firearms instructors and police trainers. Three key objectives guided the scenario development: the need for (i) a relatively complex scenario which the participants could be questioned about in detail; (ii) a scenario with challenging elements that would produce a natural physiological stress response and (iii) a realistic scenario officers might encounter in the course of their duty and be reasonably expected to respond to.

All officers encountered the same 'augmented reality' scenario, lasting four minutes, which incorporated pre-recorded and live elements. The pre-recorded elements of the incident were presented as 'live' CCTV footage and were integrated with fully-scripted, highly controlled live elements, re-enacted for each pair of participants, using three actors (one male 'perpetrator', two male 'hostages'). At the outset, the perpetrator was shown via a CCTV-feed, threatening the two hostages in a hallway (outside the classroom where they had originally been located in the briefing video). One of the hostages was then released and could be seen walking down a hallway, appearing first in the 'CCTV footage' and then in reality through a window in the classroom through to the same hallway. This visual device

was incorporated to fully establish the link between the apparent CCTV footage and elements of the scenario enacted in real-time activities. This method appeared successful as, during debriefing, a number of officers indicated surprise that any elements had been pre-recorded and all officers reported the scenario as a single integrated event. Shifting from pre-recorded footage to live interaction, the perpetrator then entered the classroom (where the officer participants were located) using a hostage as a shield and holding a knife to the hostage's neck. After issuing various demands, he set the hostage free and threw the knife to the ground before retreating to the hallway and closing the door to the classroom. He could then be seen, on the CCTV, tucking the gun into the waistband of his jeans. In the final live interaction, the perpetrator re-entered the classroom in an agitated manner, goading the officers to shoot him. The gun remained in the waistband of his trousers throughout.

Recall Tasks. The recall tasks comprised two different response formats – Free Recall and Closed Questions. In the Free Recall task, which was presented first, there were two sections. The first section requested details of the briefing information encountered at the outset (Briefing Phase). The second section requested details of the main scenario involving the 'live' CCTV footage and perpetrator (Response Phase). Instructions at the start of both sections asked participants to report as much information as they could remember about the event, emphasizing that their account should be "as complete and accurate as possible". Participants were also instructed against guessing. In the Closed Questions task, participants answered 94 questions adapted, in terms of style and content, from the type of questions posed by external investigators in such circumstances (as mentioned by Dodd & Travis, 2014). Ninety-one of these questions sought factual and verifiable information about the incident, three questions asked for a more subjective assessment of the perpetrator (e.g. "What was the demeanor of the perpetrator?" and "Describe his facial expression"). A subset of these closed questions (14 questions; *target questions*) were identified by legal and police

training advisors as important questions from an investigative perspective with respect to an officer's recall of the critical response phase. These question sub-sets were categorized as 'Perpetrator Action' (e.g. *Did he turn to the left or to the right? What position did he move his arms to?*), 'Officer Response' (e.g. *What action(s) did the other officer(s) in the room take at this point? How many shots were fired and by whom?*) and 'Perpetrator Weapon' (e.g. *Did the culprit discharge a weapon during the incident? If yes, how many shots did he fire? Where was the gun at the end of the scenario?*).

Procedure

Participants were allocated to the schedule in pairs and were randomly allocated to the role of 'Active Officer' or 'Observer Officer' by virtue of their choice of seat in the waiting area. Both officers were fitted with Polar Heart Rate monitoring belts, equipped with safety glasses, and given general instructions about their role. Active Officers were instructed to respond to the scenario event as they would normally in the course of their duty. Observer Officers were instructed to take no active response role and to simply observe what happened during the scenario. A verbal briefing by a 'senior officer' informed them that there was an on-going hostage situation involving a male perpetrator armed with a knife in a remote corridor area. They were told that negotiations had been underway but that the perpetrator had stopped communicating in the past 30 minutes. The Active Officer was provided with a training handgun loaded with five blank rounds (i.e. their weapon was available for discharge) and informed s/he was part of an initial response team with the objective of moving forward into the classroom adjacent to the corridor containing the hostages in order to tactically assess the situation and intervene, or advise other teams available to intervene as necessary.

Before entering the critical response phase, both participants, seated side by side, viewed the briefing video on a laptop screen. They were told that this was "cell phone

footage that a witness captured as the situation developed this morning". This concluded the briefing phase. At the outset of the critical response phase, both officers were then taken into the classroom where they could view the 'live' CCTV footage of the on-going incident. Both were equipped with headsets to ensure they could hear the footage soundtrack and also to mitigate any effects of any verbalization by their co-participant (some participants initiated verbal comments with respect to the evolving scenario; we noted no apparent effect of this verbalization on reporting and observed that as the scenario escalated, verbal commentary typically ceased). A confederate officer initiated the footage when they entered the room and ensured both participants stood in pre-allocated side-by-side containment positions (behind a desk) that shared an equally clear view of both the CCTV footage (within 2 feet) and live action space (within 15 feet). A senior police instructor monitored each trial from a health and safety perspective and ended each trial with a whistle blast. Each trial was captured on two digital cameras.

There was a delay of 45-50 minutes between the end of the response phase and the recall tasks. The purpose of this delay was two-fold. First, to allow attenuation of any immediate stress response and second, to mimic a minimum delay before an initial interview with an investigator. During this time, officers were seated at separate desks in silence. No discussion with their partner (or anyone else) was permitted and this instruction was closely monitored by the researcher. After the delay, participants completed the recall tasks. When they had completed the free recall component, they were given the closed questions and worked through them in sequential order. Drawing on an approach devised by Scoboria and colleagues (e.g. Scoboria & Fisico, 2013) to better understand the meaning of "Don't Know" responses in interview contexts, participants were then asked to clarify any "Don't Know"/ "Unknown" responses by selecting one of four options for each response of that type: (a) I didn't report an answer because the information was not present in the event *(no one could*

answer this question); (b) I didn't report an answer because I couldn't recall the specific information from the event *(someone else might be able to answer this question, but I can't);* (c) I didn't report an answer because I truly do not remember *(I don't know whether it's possible to answer this question or not from the information in the event)* or *(d)* I didn't report an answer because I wasn't confident enough that it was correct *(I could provide an answer if pushed, but it might be wrong).*

No time limits were imposed and participants took, on average, two hours to complete the recall tasks and final classification task. Officers were then fully debriefed and thanked for their contribution to the research.

Coding

Both free recall sections (Briefing Phase and Response Phase) were coded for quantity and accuracy. Using a coding scheme adapted from Hope, Gabbert, and Fraser (2013), each unit of information reported was categorized as either correct or incorrect. A second coder, blind to experimental condition, coded a random sample (15%) of the free recall reports. Inter-coder reliability for briefing phase recall was Kappa = .72, $p < .001$, 95% CI [0.47, 0.98] and for response phase recall was Kappa = .81, $p < .001$, 95% CI [0.58, 1.00], suggesting substantial to high levels of agreement (Landis & Koch, 1977). Accuracy rate was calculated by dividing the total correct items by total responses (correct and incorrect).

For the 94 closed questions, model correct answers were agreed by the research team in a detailed review of the scenario videos. No divergence occurred during any trial that would have resulted in a different possible answer for any question. The closed question responses were coded as either correct or incorrect. "I don't know" (and variations thereof e.g. "unknown", "not sure") responses were also recorded. Responses to questions concerning the demeanor of the perpetrator elicited subjective responses (*"he looked*

angry"), and consistent with coding conventions in previous research, were not included in the analysis of recall data.

Results

Individual officers took part in pairs (in this case, distinguishable pairs; Kenny, Kashy, & Cook, 2006) such that all participants were exposed to the same highly controlled scripted and videoed stimuli. Given this dyadic design structure, it was necessary to assess the degree of non-independence prior to proceeding with the main analyses. Following Kenny et al.'s (2006) approach, we conducted a preliminary analysis to establish the extent to which responses within the pairs were correlated. First, the dataset was restructured to apply SPSS syntax, developed by Alferes and Kenny (2009; see supplementary materials), to compute the Pearson product-moment correlation coefficient between dyad members and perform a t-test of the null hypothesis that the population correlation is 0. For the free recall data for the 38 intact pairs in the dataset, $r(38) = .12$ [-.21, .42], $t(36) = .74$, $p = .47$. The same analysis was conducted for the cued recall data. The correlation and associated t-test were also non-significant; $r(38) = .21$ [-.12, .50], $t(36) = 1.28$, $p = .21$. Given independence between dyad member scores for both recall tasks, each individual was used as the unit of analysis in subsequent analyses; see Kenny et al. (2006) for informative discussion around measuring (non)independence in dyadic data.

Physiological Response

Usable heart rate recordings were available for 61 participants in the sample (33 participants in the Active Officer condition and 28 participants in the Observer Officer condition). The mean resting heart rate (HR) recorded over a 10 min period one hour after the critical response phase was 68.01 beats per minute (bpm; $SD = 9.17$) and was roughly equivalent between groups (Active Officers $M = 68.81$ $SD = 8.68$; Observer Officers $M = 67.13$, $SD = 9.80$). HR measurements recorded during the response phase showed a range of physiological

arousal response with a range of 76-164 bpm (see Table 1). The average maximum HR (mHR) recorded during the response phase were significantly higher for Active Officers than Observer Officers, $t(59) = 2.89$, $p = .005$, $d = 0.75$, 95% CI [0.22, 1.28]. Heart rate variability (HRV; Thayer, Ahs, Fredrikson, Sollers & Wager, 2012), another measure of workload under stress measured over a 1 min period during the response phase, also differed between groups, $t(59) = -2.30$, $p = .025$, $d = 0.59$, 95% CI [0.06, 1.11]. Lower HRV is associated with increased stress (see meta-analysis by Thayer et al., 2012).

[Table 1 about here]

Recall Performance

Free recall. For the free recall data, the dependent variables of interest were quality (as reflected in the accuracy of accounts) and quantity (as reflected in the amount of information provided). As quantity is most usefully examined in terms of the amount of correct and incorrect items, it should be noted that the quality and quantity measures are not independent.

Recall of briefing phase. There was no significant difference between conditions for the amount of correct ($t(74) = 0.06$, $p = .96$, $d = 0.01$, 95% CI [-0.44, 0.47]) or incorrect ($t(74) = 0.15$, $p = .88$, , $d = 0.03$, 95% CI [-0.42, 0.49]) information reported about the events viewed in the briefing video. Similarly, there was no difference between conditions in the overall accuracy rate for this information, $t(74) = -0.35$, $p = .73$, 95% CI [-0.04, 0.02], $d = 0.13$, 95% CI [-0.58, 0.32]; see Table 2.

Recall of response phase. There was a difference between conditions for the number of correct details reported about the critical response phase, such that Active Officers reported significantly fewer correct details than Observer Officers (see Table 2), $t(74) = -2.74$, $p = .008$, , $d = 0.63$, 95% CI [0.15, 1.09]. There was no difference in the amount of incorrect information reported between the experimental groups, $t(74) = 0.87$, $p = .39$, $d =$

0.20, 95% CI [-0.25, 0.66]. The overall accuracy rate did not differ between the groups either, $t(61) = -1.46$, $p = .15$, $d = 0.32$, 95% CI [-0.77, 0.14].

[Table 2 here]

Integrating Physiological Response and Free Recall Performance

The analyses suggest a link (i) between the role the officer was assigned to (active vs. observer) and the degree of arousal experienced (using maximum HR as a proxy measure for the peak of that arousal) and (ii) between role and free recall performance, specifically the amount of correct information reported about the response phase. These associations might be formulated as $X \rightarrow M$ and $X \rightarrow Y$ respectively in terms of the meditational model $X \rightarrow M \rightarrow Y$ (where X is the independent variable, Y is the dependent variable and M is the mediating variable; Baron & Kenny, 1986). In line with Baron and Kenny's (1986) recommendations for establishing mediation, we constructed three regression equations. First, regressing maximum HR (mHR) on experimental condition ($X \rightarrow M$) was statistically significant, ® = -15.72, 95% CI [-26.77, -4.62], $t(59) = -2.89$, $p = .005$. Second, regressing correct response phase free recall performance on experimental condition ($X \rightarrow Y$) was significant, ® = 7.17, 95% CI [2.17, 12.34], $t(74) = 2.74$, $p = .008$. Finally, regressing free recall performance on both experimental condition and mHR rendered mHR significant (® = -.18, 95% CI [-.31, -.06], $t(58) = -2.76$, $p = .008$) but not experimental condition, ® = 4.81, 95% CI [-1.06, 10.33], $t(58) = -1.69$, $p = .09$. The indirect effect of the independent variable (role) on the dependent variable (correct free recall) via the mediator was significant, Sobel Test = 2.08, $p = .02$. Baron and Kenny (1986) state that a variable M functions as a mediator when the significant effect of X is rendered non-significant after controlling for M. Thus, in the current analyses, officer role was related to the degree of arousal experienced during the critical response phase and the effect of role on correct information recalled was mediated by arousal.

Although regressing HRV on experimental condition was statistically significant, ® = 10.49, 95% CI [1.41, 19.11], $t(59) = -2.30$, $p = .025$, HRV did not mediate the effect of role on recall. Experimental condition continued to predict free recall performance (® = 7.65, 95% CI [1.52, 14.06], $t(58) = 2.59$, $p = .012$, but HRV did not, ® = -.007, 95% CI [-.17, .15], $t(58) = -0.09$, $p = .93$ (*see Discussion*).

Closed Questions

The overall accuracy rate for the closed questions was 57% ($SD = 11.25$), with accuracy ranging from 28%-76% and no difference between conditions although there was a trend to greater accuracy, in terms of overall accuracy rate, in the observer condition (Active $M = .55$, $SD = .13$, 95% CI [.51, .59]; Observer $M = .60$, $SD = .08$, 95% CI [.57, .62]), $t(73) = -1.78$, $p = .08$, $d = 0.46$, 95% CI [-0.002, 0.92]. On average, officers wrote a 'Don't Know' response for 17% of the closed questions with no difference between experimental groups in the mean frequency of 'Don't Know' responding, (Active $M = .19$, $SD = .11$, 95% CI [.16, .23]; Observer $M = .15$, $SD = .08$, 95% CI [.12, .18]), $t(73) = 1.62$, $p = .11$, $d = 0.42$, 95% CI [-0.05, 0.88]. With respect to 'Don't Know' responses, participants were asked to categorize such responses to one of four categories. Notably, there was a significant effect of Officer Role on the frequency of selection of one of the categories (Category A: *"I didn't report an answer because the information was not present in the event"*; see Table 3).

[Table 3 here]

Target questions. Recall that the target questions were a subset of the closed questions identified by legal and police training advisors as critical from an investigative perspective. For analysis, the average number of correct, incorrect and don't know responses were calculated for each of the three subsets, "Precursor Perpetrator Action", "Officer Response" and "Perpetrator Weapon". For Perpetrator Action and Officer Response, there

were no significant differences between conditions for mean number of correct, incorrect or DK responses (see Table 4).

With respect to questions pertaining to the perpetrator's weapon, there was no difference between conditions for the number of questions answered correctly or with a Don't Know response. However, there was a significant difference between conditions for incorrect responses (see Table 4) and accuracy rate (Active $M = .55$, $SD = .33$, 95% CI [.44, .66]; Observer $M = .71$, $SD = .31$, 95% CI [.60, .81]), $t(73) = 2.13$, $p = .04$, $d = 0.50$, 95% CI [0.03, 0.96].

[Table 4 here]

Memory for Weapon-Related Details

Of the 39 participants placed in the role of the Active Officer, 33 of them discharged their weapon during the scenario (85%). We conducted an additional coding of the free recall data to examine how many participants spontaneously reported that the perpetrator pointed a weapon at them/in their direction in response phase (note that the gun had remained in the perpetrators waistband throughout that scene). Overall, 18% of participants spontaneously reported that a gun was pointed at them in the final part of the scenario. There was no association between Officer Role and likelihood of reporting the perpetrator pointing a gun towards the officers in the final scenario: 15% of Active officers and 22% of Observer officers reported seeing a gun in the hands of the perpetrator, $\chi^2 < 1$.

Discussion

Operationally active witnesses did not differ from their observer counterparts with respect to their recall of the briefing phase encountered prior to immersion in the critical response phase. Recall of the initial briefing phase arguably represents a baseline recall measure as arousal levels would have been equivalent at time of encoding (and our baseline

heart rate measures suggest there are no other systematic physiological differences between the groups). However, an interesting difference emerged between active and observer officers in their recall of the critical response phase. Operationally active witnesses reported significantly fewer correct details about the scenario than observer witnesses. However, there were no differences, according to role type, in the overall accuracy rate of information reported. Thus, operational witnesses, in free recall tasks at least, were able to sustain the accuracy of their accounts. Indeed, accuracy rates for freely reported information were very high across both operational and non-operational witnesses (≥92%). In light of the high profile political, legal and investigative contexts such accounts are evaluated in, the adoption of a conservative reporting strategy is not particularly surprising, and would explain the high levels of accuracy observed here (see Hope et al., 2013 for further discussion of this issue). Nonetheless, that operationally active witnesses reported significantly fewer correct details about the critical response phase than their non-operational observer counterparts is important.

Our physiological data may help account for this finding. Operationally active witnesses showed significantly higher levels of physiological arousal, as marked by higher heart rates and lower HRV, during the critical response phase of the scenario in comparison to their non-operational counterparts. It is noteworthy that significantly different heart rate measures were recorded for active witnesses despite the fact that officers in both active and observer roles were exposed to the same critical scenario and stood side by side while the scenario unfolded. In other words, higher heart rates and lower HRV did not reflect increased *physical* activity – in fact, we deliberately limited the potential for differential physical movement through the enforcement of pre-determined containment positions. Therefore, active witnesses in the current study experienced higher levels of physiological arousal or stress response as a function of the demands of their operational response role.

Mediational analyses revealed that the observed effects of role on free recall performance were related to level of stress, as indexed by the maximum heart rate recorded during the critical response phase. Thus, while it is important to consider the role of a witness to an event, the degree of arousal experienced is also an important factor. Although heart rate variability recorded during the critical response phase reflected relatively increased stress workload for active witnesses, a similar meditational relationship was not observed. This result can most likely be accounted for by the sampling period for both measurements. Heart rate typically peaked at the critical final moments in the scenario, in the same 2-3 secs, where the perpetrator turned towards the officers (i.e. the point at which 85% of active officer discharged their weapon). As such, the maximum HR measure reflects a specific instantaneous period of elevated stress. Conversely, HRV was calculated, in line with conventions over a longer period during the response phase (1 min; see Spierer, Griffiths & Sterland, 2009). As such we would not necessarily expect HRV to mediate recall performance across this longer period. Nonetheless, it is noteworthy that this measure reflected increased stress for the active witnesses across the critical response phase.

Although high accuracy rates were obtained for both groups in these free recall reports, requiring officers to respond to closed questions produced a very different pattern of results. Accuracy rates for closed questions were comparatively low for both Active and Observer Officers – the average accuracy rate was 57% meaning that just under half of the questions were answered incorrectly or with a don't know response. More importantly, there was a difference in response accuracy for information pertaining to the perpetrator's weapon (i.e., a legally relevant subset of questions) with active officers significantly more likely to provide incorrect information than observer officers.

These are important findings and, to our knowledge, this is the first study to document a physiological difference between witnesses who have different roles in responding to the

same incident, observe that the effect of role operates through an arousal mechanism and demonstrate differences in memory performance for operational versus non-operational witnesses. As such, these findings confirm the merits of considering the role of 'operational witness' when evaluating their statements.

Despite showing a physiological profile consistent with an increased stress response, active officers in the current study clearly did not experience a generalized 'catastrophic failure' of memory (in terms of the overall quantity of information reported). However, consistent with previous findings (e.g., Hope et al., 2013) they did report significantly less correct information than non-operational observer counterparts. Examination of the errors made by active witnesses in response to closed questioning highlights particular areas of vulnerability in their recollection of the incident. Specifically, as illustrated by performance on target questions, the recall performance of active witnesses was significantly impaired, relative to observer officers, for critical information about the weapon in the final moments of their interaction with the perpetrator (i.e., when threat level was greatest). Active witnesses reported less information in their responses to questions about the weapon and their responses were less accurate than observers. Active officers were also more likely than their observer counterparts to categorize their use of a 'don't know' response as "*I didn't report an answer because the information was not present in the event*" which suggests that details of the event were either not encoded in the first place or were no longer accessible. At first glance, the findings of the current study appear to be inconsistent with classic 'attentional narrowing' accounts which propose a recall advantage for central or important stimulus information over peripheral information (e.g. Safer, Christianson, Autry, & Osterlund, 1998). However, this would be a premature and likely inaccurate conclusion - particularly in the absence of data for a control, non-arousing version of the scenario. Observer officers in the current study were exposed to the same arousing encounter and displayed elevated heart rates during the

critical scenario (averaging 112 bmp) contrasting with their baseline heart rates (averaging 67 bpm). Yet, this group achieved reasonably high accuracy rates for questions pertaining to the weapon, almost certainly a high priority stimulus and focus of attention during the critical response phase. There are a few potential explanations. First, it may be that observers simply did not meet an arousal threshold likely to impair recall. It is worth noting that the average heart rate for observers is close to the 110 bpm threshold beyond which the sympathetic nervous system (SNS) is triggered (cf. the average rate of 126pm for active witnesses which is well beyond this threshold; see Woody & Szechtman, 2011). Therefore, the level of arousal experienced by observers, in the absence of further competing demands, did not necessarily impede the processing of important information in the scene and, thus, the findings are likely to be entirely consistent with previous literature. As such, moderate arousal as a function of merely witnessing a threatening incident was not responsible for reduced recall performance of active witnesses (relative to observers) in the current study. Future research might consider innovative methodological approaches where the meaning of the important stimuli is altered depending on environmental context (e.g. Pickel, 1999) and arousal level to explore these comparisons further for operationally active and non-operational observer witnesses.

Operationally active witnesses did not show a recall enhancement for critical stimuli – in fact, relative to ob. , rver witnesses, they reported fewer correct details about the critical response phase and had poorer accuracy for questions about the weapon. There are a number of possibilities as to why this might be the case. First, in light of the physiological results, it is possible that active witnesses experienced greater stress responses than their observer counterparts which may have contributed to memory impairment for details of this final phase of the scenario where the threat level (and likely associated stress) was highest. This pattern of results is consistent with the inverted U-shaped curve predicted by arousal theories

to account for performance decrements when moderate stress levels are exceeded (Morley & Farr, 2012). Second, additional cognitive load as a function of response role may have impaired their ability to process information about details of the final scene. This deficit is particularly evident for information pertaining to the fate of the perpetrator's weapon. Given that operational demands were likely to be at their greatest at this moment (i.e. attempts to attenuate immediate lethal threat), these findings are unsurprising and likely reflect reduced information processing resources. Third, the interaction between heightened stress and additional cognitive load associated with responding and attempting to neutralize the threat, may have produced impaired encoding (and/or retention) of details of the scene. As such, our findings are consistent with Morgan and Southwick (2014) who have argued on the basis of data obtained in challenging military training contexts, that memory for stressful events can be vulnerable to error and suggestion - contrary to predictions that emotionally arousing events will be remembered better than neutral events (see also Engelhard, van den Hout & McNally, 2008, Lommen, Engelhard, & van den Hout, 2013; Morgan et al., 2013). In the current study, the increased stress experienced by active witnesses may have led to more generalized processing and resulted in the rapid extraction of gist information (e.g., Payne et al., 2002; see also Qin, Hermans, van Marle, & Fernandex, 2012) that they were able to report accurately in a free recall account, but which was not sufficiently specific to produce accurate detailed information about the weapon when probed by closed questions.

The current data might also be considered in light of compensatory control models (e.g., Hockey, 1997). When processing resources are compromised (e.g., due to threat), individuals make strategic adjustments in the allocation of resources in order to maintain performance on high priority task goals (Hockey, 1997). Such adjustments often produce decrements on secondary tasks or amplify trade-offs (Hockey, 1993; Hockey & Hamilton, 1983). It has typically been assumed, here and in other research, that details associated with

a deadly weapon constitute the critical stimuli. However, there are important contextual factors to take into account. First, training guidance on firearms practice (e.g., Armed Policing Authorised Professional Practice, 2013) often recommends aiming to strike central body mass depending on the type of weapon being used and training received, which means that rather than sustaining their attention on a weapon they already know to be present, officers will re-focus their attention on a target's critical mass. Second, it may well be the case that once an officer has committed to a decision to discharge their weapon, other competing priorities take precedence including monitoring the immediate environment for further risk factors, securing the safety of oneself and others and planning the next action. Previous research has documented impaired recall and recognition of a critical (threatening) target individual for officers experiencing reduced processing capacity (as a function of exertion). However, detection and recall of additional risk factors in the environment was not impaired suggesting that attentional resources may have been diverted to risk assessment activities rather than the encoding of an unarmed albeit verbally threatening target (see Hope et al., 2013). A similar explanation may apply here and is consistent with the predictions of the arousal-based competition model (ABC; Mather & Sutherland, 2011). Future research should examine cognitive processing in the aftermath of weapon discharge to elucidate the relative roles of stress, cognitive load and competing priorities in processing an incident and the subsequent impact on memory. Furthermore, researchers (and, by extension, the legal profession and evaluators) may need to a take a more contextual perspective before assuming what constitutes 'critical' stimuli in a scene. As noted by Mather and Sutherland (2011) "priority is determined by bottom-up perceptual salience and top-down relevance" (p.19), both of which would have been determined by individuals juggling competing operational demands in the current study.

The finding that 18% of the sample (largely equivalent across both Active and

Observer witnesses) reported that the perpetrator pointed a weapon at them in the final critical scene is interesting – albeit predicted by expectation-driven processing. It is also consistent Morgan et al.'s finding that soldiers made non-trivial errors for the presence of weapons under stressful conditions (e.g. 27% of soldiers falsely reported that their interrogator wielded a weapon; Morgan et al., 2013). However, there are at least two other potential explanations that might account for this error. The first concerns a relatively simple visual effect comprising two stages – a feed-forward sweep which allows the rapid extraction of features from a visual scene followed by recurrent processing to produce a conscious experience (see Lamme, 2006). It may be that the expectation of a weapon in combination with visual processing under time pressure failed to detect that a weapon was not present, leaving (some) witnesses with the belief that they had in fact seen a weapon without the opportunity to fully process the scene. Alternatively, it may be that the reporting of a weapon simply reflects a reconstructive error in light of outcome knowledge. All officers who reported seeing a weapon pointed at them also discharged their own weapon. Knowing this outcome of their own decision-making, some almost certainly felt under pressure to justify the use of lethal force in a legally consistent manner. This is an interesting distinction that is important for investigators to consider in the evaluation of accounts of firearms incidents. Generally, officers will have made a decision to discharge their weapon as a function of their contemporaneous perception and sense-making at the scene (i.e. "What I think I see/What I think is happening") whereas their account justifying their actions at the scene is likely to be based on retrospective and necessarily reconstructive processes (i.e. "What I think I must have seen/What must have happened"). Just as legal decisions in the aftermath of a shooting are made with the benefit of hindsight and biases associated with the presence of outcome information (Villejoubert, O'Keefe, Alison, & Cole, 2006), officers' post hoc evaluations may be similarly vulnerable to the influence of hindsight and outcome information. In sum,

it is not possible to determine whether this error reflects a memory distortion or a post hoc justification informed by outcome bias. Similarly, it cannot be easily attributed to attentional phenomena (e.g. 'inattentional blindness'; Chabris, Weinburger, Fontaine & Simons, 2011) in the absence of relevant measurement data - particularly given exposure duration, the error reporting rate, and distribution of the error across active and observer conditions. Nonetheless, during debriefing, officers who had reported seeing a weapon expressed surprise when told that was not possible. Therefore, further research is necessary to disentangle the cognitive and social effects producing this erroneous reporting under stressful conditions. Indeed, the current research only considered the effects of stress at encoding on output. Given the high stakes of real-life shooting investigations, it is reasonable to assume that officers may also experience stress at the reporting stage.

Although officers took part in a challenging, tightly controlled, simulated incident that replicated high-quality training scenarios, the experience was obviously not as dangerous or consequential as a real-world incident involving lethal weapons. Furthermore, we only ran participants in one stimulus event. However, little research in this particular applied context, with the exception of studies conducted by Morgan and his colleagues (2013, 2014) in a military setting, has achieved similar levels of ecological validity (see Hope et al., 2012, 2013 for further discussion of this issue). Our decision to recruit pairs of officers was deliberate to limit any extraneous effects of law enforcement training and experience on recall performance. Of course, it is possible that the performance of the officer designated 'observer' status does not necessarily replicate the performance of a lay, bystander witness. Future research should consider the extent to which expertise or domain knowledge held by operational witnesses contributes to their subsequent recall of incident and explore whether this knowledge can be capitalized on to support retrieval for operational incidents. It should also be noted that the current research involved a single white male target - perpetrator race

was not manipulated and nor was 'decision to shoot' a key dependent variable. Therefore, the current research cannot speak to racial aspects of recent high profile police shootings in the United States, or indeed elsewhere (for recent research on race and shooting behavior, see Cox, Devine, Plant & Schwartz, 2014; Sim, Correll, & Sadler, 2013). Further research, involving high fidelity simulations and methodologically rigorous experimental designs, is needed to examine the determinants of decisions to shoot in diverse policing contexts. Finally, as is common in research investigating eyewitness recall, our analytical approach necessitated a number of statistical tests, which can increase the likelihood of Type I (familywise) error. For this reason, our interpretation of our results relies heavily on measures of effect size, rather than solely the statistical significance of any finding.

Through examining the performance of witnesses who, by virtue of their duty, are required not only to witness but also to react and respond under stressful conditions, the current research constitutes an important and timely contribution both to the psychological literature and wider policy concerns in legal and investigative contexts. To date, little research has systematically examined the recall of officers for challenging or threatening operational incidents, particular those involving use of lethal force. Yet, the investigation of such incidents constitutes a major and high profile task both for police forces and external agencies such as the Independent Police Complaints Commissions (IPCC) established in the UK under the Police Reforms Act 2002. Internationally such investigations are typically high profile, attracting both public and media attention, and have serious consequences for the officers involved (Goodwill et al., 2009). Thus, the development of evidence-based policy and investigative practice is critical. The current results document the vulnerability of memory in this context and highlight the need for well-informed approaches to eliciting information from operationally active witnesses.

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Table 1. Means, standard deviations and 95% CIs for maximum heart rate (mHR) and heart rate variability (HRV) by experimental group.

	Active Officers		Observer Officers	
	Mean (SD)	95% CI	Mean (SD)	95% CI
Max HR (mHR)**	126 (19.95)	[119.38, 132.89]	110 (22.58)	[102.44, 118.94]
HR Variability (HRV)*	22.34 (14.89)	[17.81, 27.51]	32.83 (20.63)	[25.58, 40.35]

* $p < .05$; ** $p < .01$

Table 2. Means, standard deviations and 95% CIs for correct and incorrect items reported and accuracy rate by experimental group.

		Active Officers		Observer Officers	
		Mean (SD)	95% CI	Mean (SD)	95% CI
Briefing Phase	Correct	47.46 (17.37)	[41.97, 52.68]	47.24 (16.01)	[42.32, 52.45]
	Incorrect	4.72 (5.66)	[3.16, 6.86]	4.54 (4.21)	[3.25, 6.00]
	Acc. Rate	.91 (.08)	[.88, .94]	.92 (.07)	[.90, .94]
Critical Response Phase	Correct**	38.67 (10.17)	[35.61, 41.97]	45.84 (12.59)	[42.02, 50.03]
	Incorrect	1.64 (2.18)	[1.00, 2.40]	1.29 (1.05)	[.97, 1.66]
	Accuracy	.96 (.04)	[.95, .97]	.97 (.02)	[.96, .98]

** $p < .01$

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Retrograde Amnesia: Delayed Forgetting after Concussion
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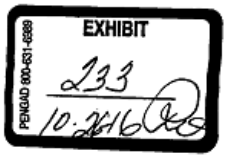

METHOD

We waited on the football field until a player was injured, and then immediately examined him neurologically and tested his memory status. The neurological exam consisted of a brief test for funduscopy, pupil reaction, and extraocular-muscle function. All six concussed subjects were interviewed within 30 sec of the time of injury, were interviewed again within 3 to 5 min, and were reinterviewed at frequent intervals as the field situation permitted (usually, every 5 to 20 min). Memory status was examined by asking the player to state his name, to say where he was, who his opponents were, and to describe the events just preceding his injury.

In addition to the concussed players, 12 control players were interviewed. Of these 12, 8 had suffered a significant injury (for example, torn knee ligaments, broken nose, pinched nerve) other than a concussion and, like the concussed players, were first interviewed within 30 sec of the time of injury. There were also 4 noninjured players, who were first interviewed within 30 sec of the time at which they left the field after a substitution.

RESULTS AND DISCUSSION

The neurological exam for all six concussed subjects was unremarkable. The interviews revealed for all six a period of lucid memory immediately after the mild concussion-inducing blow. However, this period of intact recent memory was then followed by a relatively complete amnesia for events occurring just before the blow (retrograde amnesia). The same sequence of events was experienced by all of the concussed football players we observed, but did not occur among the dozen control subjects ($p < .00005$ by Fisher's exact-probability test).

The data are not as clear with respect to the permanence of the amnesia. Four of the six concussed athletes failed to recover memory for the recent retrograde events, but only two of these four could be followed for as long as four days after the injury. One subject achieved full recall of events, and a second subject achieved partial recall. Opportunity for relearning through game films and discussion could not be eliminated, however, and it is possible that these subjects did not recover memory but relearned the details of those events about which the investigators questioned them.

The delayed forgetting was quite striking. One concussed player, immediately after injury, told the interviewer that he had been hit "from the front while I was blocking on the punt." Questioned 5 min later, he said, "I don't remember what happened. I don't remember what play it was or what I was doing. It was something about a punt." Clearly, the details of events occurring just before the amnesia-inducing event were stored