Background
Sleep-related fatigue has a negative impact on decision performance (Pilcher & Huffcutt, 1996; Lopez et al, 2012 for a review), and its effects on cognitive functions are well known (Lim and Dinges, 2012). Pilcher and Huffcutt, 1996): performance on tests of simple functions (e.g., psychomotor vigilance and executive attention) declines considerably; more complex functions (e.g., short-term memory) are moderately affected; and the most complex functions (e.g., fluid reasoning) are largely unaffected. Less is known, however, about the nuanced effects of fatigue on metacognitive monitoring and decision behaviour.

Metacognitive Monitoring
Monitoring cognition is crucial for good decision making. For example, we should be confident in our judgements (a monitoring experience) when they are accurate. This can lead to reckless decision errors otherwise. Limited work has found that a single night of total sleep deprivation (TSD) did not impair metacognitive abilities (Baranski, 2007). Such findings are encouraging and in need of replication and extension.

Decision pattern analysis
Good decision making can refer to various aspects of behaviour. For example, executing effective actions and rejecting poor ones are both good decisions. To capture various aspects of decision behaviour, we used a Medical Decision-Making Test that requires participants to diagnose and treat patients. On the basis of their answers, aspects of their decision-making behaviour can be described by five variables: Competence, Optimality, Recklessness, Hesitancy and Decisiveness (see Jackson, Kleitman, Stankov & Howie, 2015). How sleep-related fatigue affects these patterns was investigated for the first time here.

Aims and hypotheses
1. To replicate previous research demonstrating that performance on tests of cognitive functioning are most affected in a bottom-up fashion the morning after a night of total sleep deprivation (TSD) and continue to suffer with repeated continued restricted sleep (PSD).
2. To replicate and extend findings related to the trajectory of metacognitive confidence of these manipulations.
3. To concurrently investigate decision patterns for the first time to investigate how the trajectory of decision metrics relates to cognitive and metacognitive performance.

Conclusions
• Total sleep deprivation had clearly negative effect, but was largely remediated with a single night of five hours sleep.
• These negative effects were not consistently observed across the range of cognitive functions.
• Participants adjusted their confidence appropriately given the changes in their performance.
• However, changes in recklessness and hesitancy indicated small increase in overconfidence errors.
• Performance decline in the real-world tasks may be the result of a metacognitive shift that leads to errors that cause more detrimental outcomes.

Method
Participants
Fourteen Australian Army personnel volunteered to participate in the study (all Male, Mage = 24.36 years, SDage = 2.84, age range: 20 - 30 years).

Measures
Control measures
1. Driving and Military Experience Questionnaire
2. Epworth Sleepiness Scale
3. Big-Six Personality Inventory
4. Self-control Scale
5. Barratt Impulsiveness Scale 11
6. Raven’s Advanced Progressive Matrices

Repeated test battery
7. Simple Reaction Time
8. Spatial Sroop Test
9. Predictable Switching (Digits)
10. Running Letters Test
11. Medical Decision-Making Test
12. NASA Task Load Index
13. Number Series Test

Procedure
The experiment ran over two consecutive weeks beginning on a Monday. During Week 1, participants completed the control measures. In Week 2, participants received no sleep (TSD) from arrival (8am Monday) until 1am Wednesday; 5-hour-per-night PSD cycle for the following two nights; an extended recovery sleep opportunity Thursday night. Nine administrations of the performance battery took place during this week. The protocol is represented in Figure 1.

Results

Figure 1. Protocol

Figure 2. Standardised week two results in relation to Monday morning performance for simple reaction time and executive functions.

Figure 3. Standardised week two results in relation to Monday morning performance for the number series test (a measure of Gf), MDST Diagnostic accuracy (a measure of Gm), and MDMT confidence

Figure 4. Standardised week two results in relation to Monday morning performance for the decision patterns obtained in the MDMT

Vigilance and Executive Functioning
Repeating previous findings, the effects of sleep loss were most pronounced for the simple reaction time and inhibitory control tasks (Figure 2).

Cognition and Metacognition
Gm was relatively unaffected. Gm was moderately affected (Figure 3). Confidence largely mirrored changes in Gm. That is, participants appeared capable of detecting change in performance when sleep deprived.

Decision Patterns
Significant declines in optimality and decisiveness mirrored declines in accuracy and confidence (Figure 4). Competence deviated little from baseline. That is, participants’ overall decision error rates were not noticeably affected by TSD or continued PSD.

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