BRAIN MAPPING IN AIRCRAFT PILOTS IN-FLIGHT:
MONITORING AND ANTICIPATION IN CHALLENGING SITUATIONS

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Monitoring and anticipation are two of the main components of situation awareness (SA) [1], [2], (Figure 1), one of the necessary key competencies of pilots [7]. Only if pilots are able to properly use their monitoring and anticipation mechanisms, they are able to reliably, adaptively, and successfully interact within their socio-technical system and better react to surprising, challenging or ambiguous situations [5]. Consequently, we were interested in neurobiological correlates of gaining SA and anticipating future aircraft states.

SUBJECTS & METHODS The study was conducted with 19 male professional aircraft pilots (age: 37±7 years, flight hours: 5,500±3,000h). Subjects performed 23 trials of a novel monitoring and anticipation task for aviation (Figure 2), while undergoing functional magnetic resonance imaging (fMRI) in a 3 Tesla Siemens TIM Trio MR scanner (610 volumes, TR/TE=1800/33ms, resolution=$1.2\times1.2\times1.5mm^3$). Data pre-processing and analyses were performed in SPM12b (slice-timing correction, realignment, unwarping, normalization, and 6mm smoothing).

RESULTS RFX group analysis showed strong activation in areas attributed to monitoring during PRE and POST conditions (Figure 4). These regions included visual areas encompassing the bilateral geniculata extending to the thalamus, the visual cortex and areas along the ventral and dorsal visual stream. Furthermore, sensory (S1, frontal insula) and motor areas (M1, [pre-] SMA) were also found to be active which can be explained by the button press required during the POST condition. In the prefrontal cortex (PFC), activation was found in the dorsolateral PFC (DLPFC), a region associated with working memory and executive functions, and in the lateral orbitofrontal cortex, which is linked to decision making and information integration. In addition, Broca's area, which is well-known for language production and related tasks, was active. During anticipation (PRE>POST), the most prominent activation was in the ventral striatum and putamen (Figure 5).

CONCLUSIONS The ventral striatum and putamen are well known for the processing of present and future reward contingencies in e.g., monetary tasks [9]. Recent studies have shown that the ventral striatum is highly context-dependent, beyond its function of reward prediction error estimation [4], which suggests the presence of an active and situated inference strategy for detecting features in the environment that are relevant for action [8]. Furthermore, activation in the putamen is typically associated with motor control, i.e. performance and preparation [10]. The result that putamen activation was higher during anticipation (PRE>POST), i.e. when no actual motor action was performed, clearly suggests that the anticipation of future aircraft states is supported by embodied experience, rather than only memorizing flight parameters using abstract working memory. Firstly, this indicates that the employed paradigm was sufficient for pilots to be immersed in the task. Secondly, this finding is yet another empirical support for present-day cognitive science theories of embodied, situated, and enactive cognition [11]. The activation in Broca's area and DLPFC during monitoring (PRE and POST) indicates that language, syntactical reasoning, and communication are also required for operations within complex task contexts [3]. While anticipation highlighted the role of ventral striatum and putamen, activation of these prefrontal regions suggests successful anticipation by facilitating understanding and maintenance of SA.

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What is situation awareness (SA)?

Theory & Concept

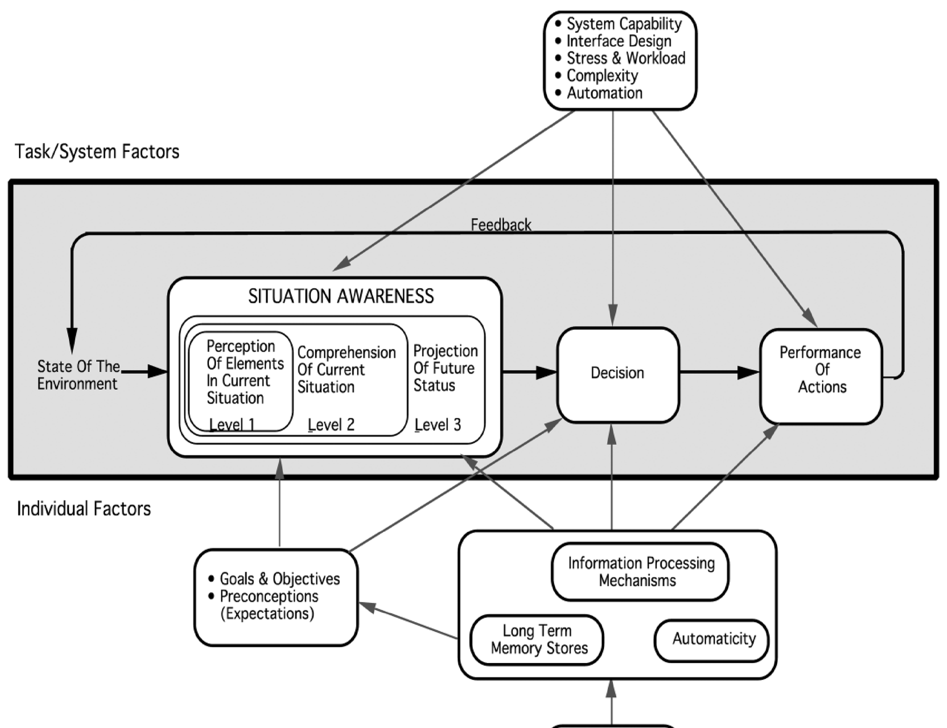

Figure 1: Model of situation awareness in dynamic decision making (DM); taken from [1].

Pilot Competency

"Perceives and comprehends all of the relevant information available and anticipates what could happen that may affect the operation." [6]

Monitoring & Anticipation

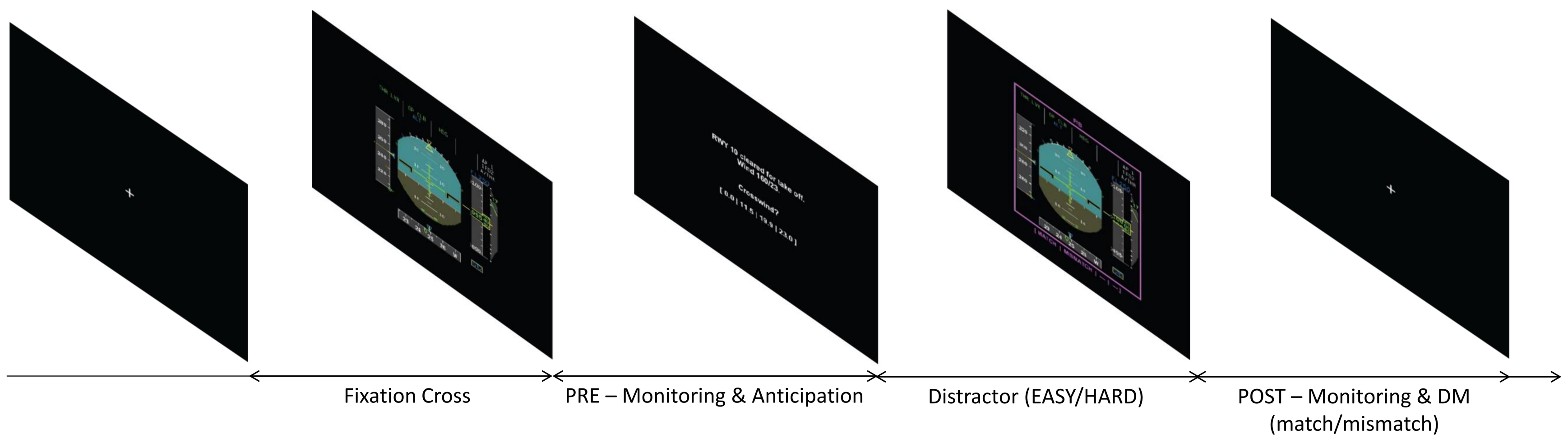

Figure 2: Monitoring and Anticipation. During the monitoring and anticipation task trials, pilots at first saw a short video clip of a realistic primary flight display (PRE; monitoring and anticipation). After 8 seconds an aviation-related cognitive distractor, a decision between head or tail wind (EASY) or a crosswind calculation (HARD) was presented, while the playback continued off-screen. 12 seconds later, the film sequence reappeared and the subject had to decide if the flight dynamics were consistent or incompatible (e.g., illegal mode change, wrong altitude) with the first part of the video (POST; monitoring and decision-making; duration between 5.00 and 12.65 seconds).

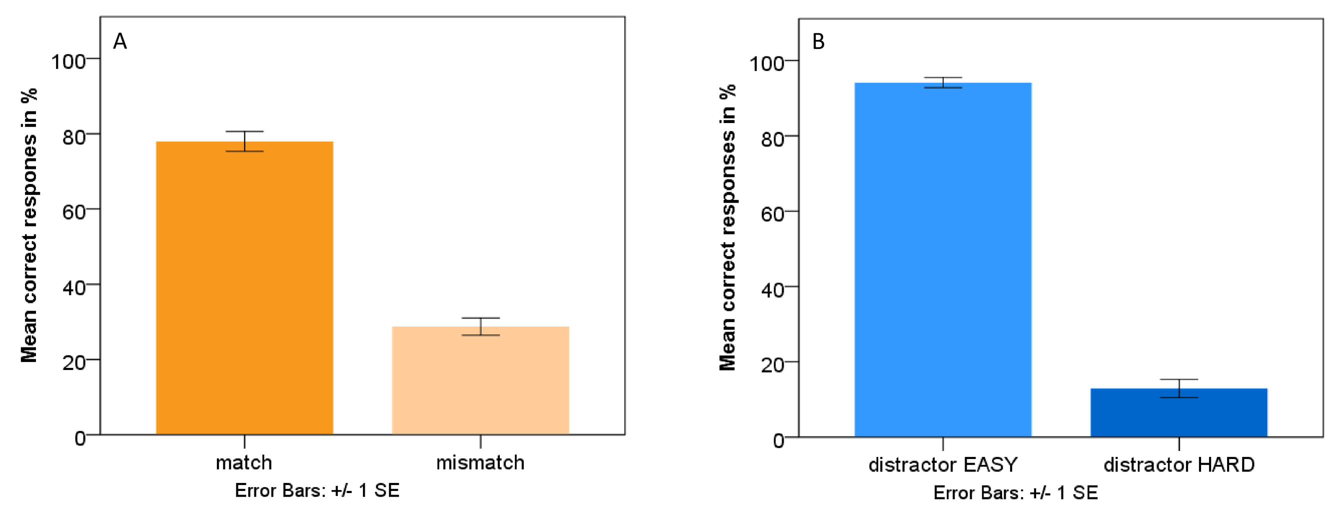

Figure 3: A) Correct response rate for the match and mismatch condition, and **B) correct response rate** for the easy and more difficult distractor; both in percent.

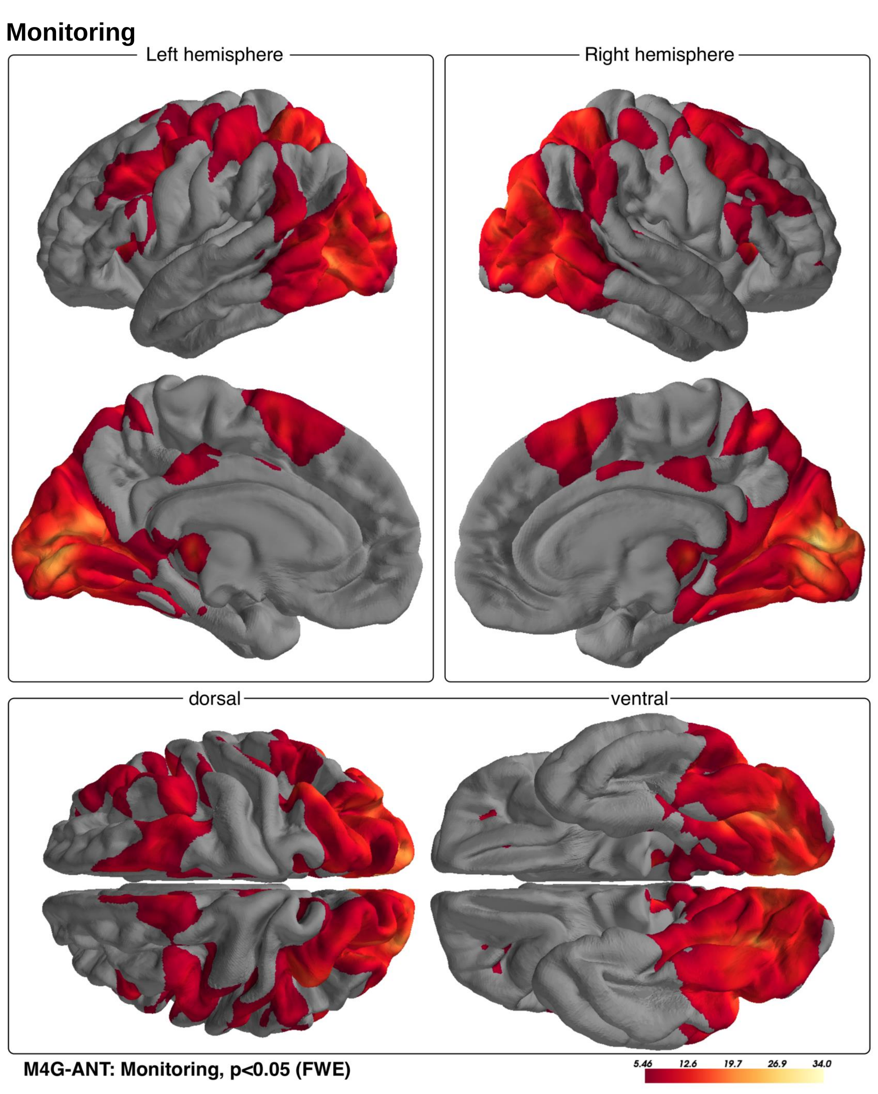

Figure 4: Brain activation during Monitoring (PRE and POST). For the monitoring contrast (in PRE and POST), the significance threshold was set to p<0.05 (FWE wholebrain corrected).

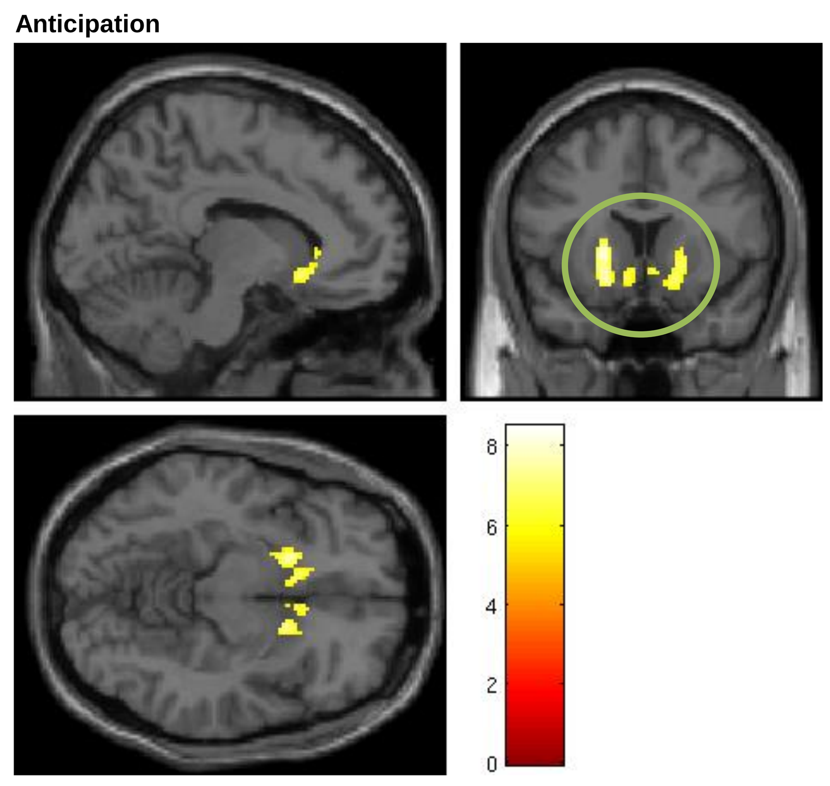

Figure 5: Brain activation in the Ventral Striatum and Putamen during Anticipation (PRE>POST). To contrast anticipation (PRE>POST), the significance threshold of the resulting t-maps was set to p<0.05 (FWEc).

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