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BEHAVIORAL INDICATORS IN AIR TRAFFIC CONTROL: DETECTING AND PREVENTING PERFORMANCE DECLINE

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Air traffic controllers are responsible for the safety and efficiency of air traffic and therefore must maintain a consistently high standard of performance. However, performance can be negatively affected by factors such as workload and fatigue, potentially leading to performance decline and performance-related incidents. Real-time identification of negative influences would facilitate timely implementation of supportive strategies prior to performance decline. The current study aimed to explore the concept of 'behavioral indicators' to identify when a controller was reaching a performance limit. A second aim was to capture behavioral indicators associated with performance influencing factors. A total of 65 controllers spanning Tower, Approach and Enroute facilities across the United States of America were interviewed. Findings revealed that controllers were familiar with the concept of behavioral indicators, and that indicators were associated with specific performance-influencing factors. Implications for implementing behavioral indicators training in control environments are discussed.

Air traffic controllers are responsible for the safety of air traffic. It is essential that air traffic controllers maintain a consistently high standard of human performance in order to maintain flight safety and efficiency. Air Traffic Management is remarkably reliable (Amalberti & Wioland, 1997), however, controllers' performance can be negatively affected by performance-influencing human factors such as workload and fatigue (e.g. Cox-Fuenzalida, 2007), potentially leading to performance decline and performance-related incidents. Current mitigations to address these impacts on controller performance include various operational mechanisms, such as sector caps, traffic restrictions, and fatigue breaks. These techniques are very effective at supporting controller performance; however, less is known about preventing or mitigating these performance-related influences dynamically. Detecting the performance-related limits in real-time could allow for the implementation of supportive strategies prior to a performance decline or performance-related incident.

Real-time identification of indicators of potential performance decline is one approach that may permit identification and mitigation of potential performance influences to prevent

performance decline. Edwards, Kirwan, Sharples, and Wilson (2016) explored the concept of behavioral indicators with 20 controllers from an Enroute facility in Maastricht, Netherlands. Behavioral indicators were identified that were common across all controllers interviewed. However, the sample was limited to European-based, Enroute controllers. The current research aimed to gain further insight into the concept of indicators and extend Edwards et al. (2016)'s findings by including controllers from Tower, Approach and Enroute control facilities across the United States of America.

Method

A total of 65, one-hour semi-structured interviews were conducted with controllers. Interviews were conducted in-person at three separate facilities: Tower Control, Terminal Radar Approach Control (TRACON), and Enroute. Facilities were selected by the FAA Human Performance team in association with a National Air Traffic Control Association (NATCA) national representative. The interviews included 10 open-ended questions which related to five areas of interest, including current use of indicators in an air traffic control settings, and generalization of indicators between controllers. At each interview, a NATCA representative was present in addition to the researcher. Interviews were transcribed orthographically, and thematic analysis was applied.

Out of a total of 65 controllers, 20 were Enroute controllers, 23 were Tower controllers and 22 were Terminal Radar Approach controllers (TRACON). Ages ranged from 21-56 years old. Years of experience post-certification ranged from 1-30 years, with 94% of participants certified professional controllers (CPCs). Four participants had been checked out of the academy but were not yet certified on their control positions (6%); for these participants, experience post-academy ranged from three months to two years. A total of 38 participants worked as On the Job Training Instructors (OJTIs), 14 from the Tower environment, 15 from TRACON and 9 from Enroute control. Years of experience as an OJTI ranged from three months to 25 years. In total, eight participants were also Operational Supervisors; three from the Tower environment, two from the TRACON environment and three from the Enroute environment.

Results

Controllers Perception and Use of 'Behavioral Indicators' of Performance

Nearly all of the controllers (64/65) were familiar with the concept of indicators and agreed that behavioral indicators occurred in the operations room; one new trainee, with three months post-academy experience, was the exception. In general, participants characterized indicators as cues that a controller (themselves or a colleague) was not completely comfortable with the control task, for example, when colleagues repeated 'say again' instructions to pilots, or when surprised by an aircraft on the radar screen. Indicators appear to serve as a mechanism to protect performance, and prevent performance decline during operations, cueing controllers to mitigate (such as through a change in control strategy) dynamic influences that can negatively affect performance. Controllers naturally monitored colleagues for indicators in addition to themselves, and once identified, applied a compensation strategy to mitigate the cause and support performance, for example, increasing the safety buffer between aircraft. The perception and use of indicators are therefore critical elements in maintaining a consistently high performance.

Indicators are Learned Through Experience

Indicators of potential performance decline are not formally taught but instead are learned through experience: *"The more you see, the more you know, 'ohh I'll never do that again'"* (Participant 23, TRACON). As a result, indicators are usually not discussed with other controllers and the opportunity to learn from other colleagues is limited. In addition, inexperienced controllers such as trainees are more vulnerable to performance decline without the learned experience that a performance limit is being reached.

Individual Differences in Observable Indicators

` Despite no formal training, findings showed that a majority of indicators were shared by every controller interviewed. Controllers' opinions regarding whether indicators were consistent between individuals were divided, however. While some believed indicators would be relatively similar between controllers, others believed that indicators were specific to the individual: *"Everyone is so different on how they interact with people. So, to generalize it, it'd be very tough.* (Participant 5, TRACON). The indicators used at the different facility types did not vary. The phase of control or a particular airspace may result in different compensation strategies employed, but the majority of the indicators were repeated in all facilities. This is an important finding, with implications for training and sharing of indicators.

Individual Differences in Awareness of Indicators

Awareness emerged as integral to the use of indicators; controllers needed to be aware of their own or colleagues' indicators in order to adapt to the situation and protect performance. Participants differed in the extent of conscious awareness of personal indicators. A majority of experienced controllers could identify personal indicators, although several other controllers suggested that they could 'sense' when they are reaching a performance limit, but not identify how they knew: *"I didn't even think about it myself until I just said it to you. I think I kinda knew it in the back of my mind"* (Participant 10, TRACON). It was reported to be easier to identify indicators in colleagues than self-indicators.

Indicators are Associated with Specific Performance-Influencing Factors

Participants were presented with a list of nine factors, including workload, fatigue, stress and situation awareness that are known to affect controller performance (e.g. Edwards et al., 2016). Participants were asked to identify internal and external indicators that were believed to be associated with each factor. Due to space constraints, three of the nine factors are presented below: workload (low and high), fatigue, and situation awareness.

High workload. Participants reported internal and external indicators of potential performance decline that were associated with high workload (Table 1). Changes to subjective feelings and performance changes were reported as important indicators that a controller may be reaching the edge of performance: *"The amount of times you hear, say again, the amount of uhs, you hear, the extremely loud typing, or the stomping of the foot pedal, they're all the same cues. And it doesn't matter if it's because of an internal factor or an external."* (Participant 7, Enroute). Because indicators were associated with specific factors (such as high workload), indicators provided controllers with information about effective mitigative compensation strategies. However, the specific compensation strategies would be specific to the airspace and the situation.

Table 1.
Internal and Observable Indicators of Performance Decline Associated with High Workload.

Cognitive Changes	Changes to control	Physiological changes	Performance changes
Don't know the next steps	Reactive	Faster heartbeat	Miss actions
Calls are a surprise	No back-up plan	Red face	Less negotiation
Mind racing/ 'busy in head'	No space for unexpected events	Sweating	Mixing call signs
Tunnel vision	Future plan reduces in minutes		Can't see solutions
Filtering out information; stop hearing readbacks	Prioritize ineffectively		Overlook aircraft

Low workload. In comparison to high workload, indicators related to low workload reflected a potential influence on performance through boredom or relaxation, leading to distraction: *"One of our tankers said they wanted an extra-long- a downwind because of a seat change. We said, 'Sure'. And then, we started talking…. And the next thing you know, this guy is 20 miles passed where he's supposed to be"* (Participant 7, Enroute). A particularly interesting finding was that controllers are more prepared to approve pilot requests in low workload situations, including shortcuts, which could create unfamiliar control situations: *"You're trying to be more expeditious when you don't have a lot of workload, and you end up putting aircraft where they aren't normally. It can put someone really out of place and get you in trouble"* (Participant 15, TRACON). Common indicators for low workload are presented in Table 2.

Table 2.
Internal and Observable Indicators af Performance Decline Associated with Low Workload.

Cognitive Changes	Control changes	Visible cues	Performance changes
Forgetting	Leave situations develop longer	Sit back	Overlooking aircraft
Easily distracted	Create more complex situations	Look away from radar screen	Forgetting aircraft
Reduced self - awareness	Less safety buffer	Talk to colleagues	Repeated mistakes

Fatigue. Controllers differentiated between tiredness, such as not sleeping well, and mental fatigue, resulting from the time and workload on session: *"Those are two completely different things. [Mental fatigue] You could hear the door open, and you're screaming for him to help you out"* (Participant 1, Tower). Sleepiness however, was largely felt to disappear after the first session:*"Once you get engaged in the operation, it'll go away pretty quickly."* (Participant 5, TRACON). Indicators of fatigue are presented in Table 3.

Table 3.
Internal and External Indicators of Performance Decline Associated with Fatigue.

Cognitive Changes	Control Changes	Visible cues	Performance changes
Slower	Less flexible	Less active	Multiple small mistakes
Not as sharp	Longer to see solutions	Quieter	Missing frequencies, transmissions
Mild confusion	Slower reactions	Yawning	Mixing call signs
Forgetting/surprised	Reactive control	Laid back in chair	Late on tasks
Extra time thinking			Incorrect plan without realization

Situation awareness. Controllers defined situation awareness as 'the picture'. As one controller described: *"You have to know where everybody's at, what they're doing… what they're gonna do in the next 10 minutes"* (Participant 14, Enroute). The loss of situation awareness was reported to be progressive and occur in stages, which were associated with different indicators: "*If you don't get catch it – it's easy to drown faster when you're already drowning–you get the first one [aircraft] and something happens. You're so focused on that, that when the other four get in you don't have time to sit there and do your plan.* (Participant 14, Enroute). Because of this progression, a distinction was made between losing the picture and having lost the picture. The progressive decline was only reported under conditions of high taskload. During low taskload, the loss of awareness was often instantaneous, potentially due to reduced task engagement and increased vulnerability to distraction.

Table 4.
Internal and External Indicators of Performance Decline Associated with Situation Awareness

Cognitive Changes	Control Changes	Visible cues	Performance changes
Running behind traffic	Reactive	Zig-Zag head movement	Falling behind
Thinking whilst giving clearance	Keep traffic static Build plan as go	Slow at task	Unsafe clearances
Tunnel vision	Reduce complexity	Silent	Missing calls
	Conservative clearance		Unexpected decisions

Discussion

Findings revealed that indicators were used in an air traffic control setting as an indication of when a controller was reaching the edge of performance, or a factor was negatively influencing performance. It was considered a natural process that controllers used. Participants confirmed that specific factor influences on performance were associated with specific internal and external indicators. Awareness emerged as an integral element in the use of indicators;

controllers needed to be aware of their own or colleagues' indicators in order to apply compensation strategies and therefore maintain performance. This study found evidence of individual differences in overall levels of awareness. This was especially true of inexperienced controllers who had not yet developed the awareness to identify indicator s and apply adaptive strategies. Indicators were found to be learned through experience rather than being formally taught. Because indicators are learned, there was an expectation that indicators are specific to the individual rather than similar between controllers. If controllers had greater awareness that indicators are used consistently, indicators and associated compensation strategies could be shared. Training on self- and colleague- indicators may support trainees to better protect performance whilst developing the required experience to identify additional indicators. In addition, a standardized list of generic indicators to look out for may be useful to trainees whist building awareness and experience. Awareness of common indicators would also be beneficial for new OJTIs and Supervisors who are still developing awareness of their colleagues' indicators (e.g., a new trainee, or a supervisor assigned to a new sector or facility).

These findings are particularly important given the current changes to the ATC environment during the pandemic. With low traffic levels, controllers face the risk associated with low workload, in addition to increased stress. Lower staffing levels may result in occasional spikes in workload. Controllers would benefit from training on the indicators and supportive strategies now, and as traffic increases. The unpredictability can lead to higher risk. Arming controllers to manage their response would be beneficial. Future research should explore program-specific training that would be most appropriate for specific roles to facilitate awareness and use of indicators to prevent performance decline and potential performance related incidents.

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