

Narrative Review

Post-shift diagnostic insight in radiography: Incubation and the temporal extension of clinical reasoning

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ABSTRACT

Objectives: Diagnostic radiography requires sustained visual attention, rapid technical execution, and continuous evaluative judgement under conditions of high cognitive load. In practice, radiographers must integrate patient presentation, positioning, radiation safety, workflow demands, and image quality assessment in real time. Many radiographers also report that insights about positioning adequacy, subtle abnormalities, or possible oversight arise only after the clinical shift has ended. Although this experience is widely described informally, it has not been formally examined within the diagnostic radiography literature. This narrative review explored whether post-shift diagnostic insight can be understood through evidence on clinical reasoning, perceptual expertise, incubation, and post-task associative processing.

Key Findings: The reviewed literature suggests that diagnostic expertise depends on rapid pattern recognition supported by executive control, but that complex or ambiguous cases may remain only partially resolved during high-pressure clinical work. Research on incubation, mind-wandering, and perceptual learning indicates that periods of reduced cognitive demand may enable continued reorganisation of previously encoded information, allowing overlooked details, alternative interpretations, or unresolved concerns to become more salient. This process provides a plausible account of how insight may emerge after focused clinical engagement has ceased.

Conclusion: Post-shift diagnostic insight can be conceptualised as a continuation of diagnostic reasoning rather than delayed reflection alone. Recognising this temporal extension of clinical reasoning has implications for practice, education, and workforce design.

Implications for practice: Structured opportunities for case revisitation, psychologically safe discussion of delayed recognition, and educational approaches that acknowledge cognitive recovery, may support adaptive expertise, strengthen error recognition, and contribute to more sustainable radiography practice.

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Introduction

Diagnostic radiography demands sustained attention, rapid technical execution, and continuous clinical judgement. Radiographers must integrate referral information, patient presentation (physical and emotional), positioning decisions, radiation safety considerations, and image quality assessment in real time. In acute settings, particularly trauma and emergency imaging, decisions are made under conditions of time pressure and high cognitive load. Clinical reasoning in radiography is therefore not merely procedural; it is a dynamic process involving pattern recognition, situational awareness, and evaluative judgement.^{1–3}

Anecdotally, many radiographers informally report that insights regarding a case, such as reconsideration of positioning adequacy, subtle anatomical alignment, or potential missed pathology, emerge after a shift has ended. These moments often occur during low-demand activities such as driving home post-shift or engaging in routine domestic tasks. While such experiences are rarely examined within radiography literature, they align with established cognitive mechanisms described in creativity and problem-solving research, particularly the incubation effect.⁴ The incubation effect refers to improved problem solving following a period of disengagement from focused task engagement.⁴ A meta-analysis by Sio and Ormerod (2009) demonstrated that incubation periods can enhance solution generation, particularly when the intervening task imposes low cognitive demand.⁴ Rather than representing cognitive inactivity, these periods appear to afford continued associative processing outside conscious awareness.⁵ Subsequent laboratory studies have confirmed that engaging in activities that require little mental effort⁶ during the incubation period, facilitates creative insight compared with cognitively demanding distraction,^{7,8} sleep⁹ or sustained effort^{7,10} on the focal or a related problem.

Neuroscientific research provides a complementary account. Creative idea generation and insight involve dynamic interactions between the executive control network¹¹ and the Default Mode Network (DMN). The DMN is a connected set of brain regions active in the absence of external cognitive demands, and inhibited by goal-directed, or effortful cognition.^{12,13} The executive control network supports goal-directed cognition.¹⁴ Hence during resting states and most demanding cognitive tasks, the DMN and executive control network are mutually antagonistic: when one is active, the other is suppressed.^{15,16} Internally oriented cognition, such as mind-wandering, constructive daydreaming, and evaluation of creative ideas, however, appears to be an exception. Rather than functioning antagonistically, these networks cooperate during creative cognition,^{17,18} with executive processes suppressing salient concepts that might otherwise interfere with creative novelty¹³ and DMN activity supporting associative recombination.^{19,20} Low-demand states may therefore allow previously encoded problem representations to be creatively reorganised outside of conscious awareness, while the subsequent suppression of salient but irrelevant concepts, produces the subjective experience of sudden clarity.

Within clinical practice, expertise has been linked to rapid pattern recognition and the integration of perceptual and conceptual knowledge.²¹ In medical image interpretation, experts demonstrate more efficient visual search strategies and superior discrimination of subtle abnormalities compared with novices.^{22–25} However, much of this literature focuses on in-task performance rather than post-task cognitive processing. Little attention has been given to how unresolved clinical cases may continue to be processed after the immediate imaging encounter has concluded. Understanding diagnostic reasoning as confined solely to the imaging suite risks oversimplifying the cognitive

architecture of expert practice. Radiographers frequently encounter ambiguous findings, borderline positioning adequacy, or complex trauma presentations that may not yield immediate closure. From a cognitive perspective, such partially resolved representations likely continue to be processed beyond the shift itself. Low-demand post-shift states may facilitate associative restructuring, perceptual learning consolidation, or the recognition of alternative interpretations.²⁶ These processes may contribute to adaptive expertise, error recognition, and refinement of future performance.

This paper advances a conceptual argument that post-shift diagnostic insight in diagnostic radiography reflects continued cognitive processing rather than isolated moments of reflection. Drawing on evidence from incubation research, mind-wandering studies, and cognitive neuroscience, the paper proposes that clinical reasoning, for example the discovery of an error or pathological detail, extends beyond active image acquisition to perceptual learning and long-term improvement in skills. By framing post-shift insight as an emergent property of professional expertise rather than anecdote, this perspective invites reconsideration of how diagnostic expertise functions, how reflection is structured in education, and how cognitive recovery contributes to clinical accuracy and workforce sustainability.

Methods

This narrative review synthesised literature from diagnostic radiography, medical imaging, medical education, cognitive psychology, and cognitive neuroscience to examine whether post-shift diagnostic insight can be conceptually understood through mechanisms of incubation and associative processing. A structured search was conducted in March 2026 using PubMed, Scopus, CINAHL, and PsycINFO. Search terms were combined using Boolean operators and included combinations of “radiography”, “medical imaging”, or “radiographer” with “clinical reasoning”, “diagnostic reasoning”, or “image interpretation” and with “diagnostic error”, “perceptual error”, “incubation”, “creative insight”, “mind-wandering”, “default mode network”, “cognitive load” and “expertise.” Reference lists of key articles were manually screened to identify additional relevant publications. The review prioritised peer-reviewed empirical studies, meta-analyses, and theoretical papers published in English from 1965 onwards. This date was selected to capture literature published following the seminal work of Norman and Shallice (1986) on attention, executive control, and automaticity, which provides an important theoretical foundation for understanding cognitive processing and expertise development.¹⁴ Studies were not excluded based on research design, as the aim was to capture empirical, theoretical, and conceptual contributions relevant to the proposed model. Articles were screened initially by title and abstract, followed by full-text review where relevance was uncertain. Publications were retained if they contributed substantively to one or more of the three conceptual domains underpinning the review: (1) clinical reasoning, diagnostic expertise, or diagnostic error in imaging practice, (2) incubation, mind-wandering, creative insight, or DMN function, and (3) perceptual learning, expertise development, or cognitive processing associated with professional performance. Articles focused solely on technical imaging procedures, equipment performance, or unrelated clinical topics without a cognitive or educational component were excluded. Given the conceptual and interdisciplinary nature of the review, article selection was guided by relevance to theory development rather than exhaustive identification of all available literature.

Given the integrative aim of the paper, a narrative synthesis approach was adopted rather than a systematic or scoping review

methodology. Narrative reviews allow researchers to synthesise existing knowledge through critical interpretation and integrative analysis rather than quantitative aggregation.²⁷ This approach enables broad exploration of interdisciplinary practice and supports identification of conceptual linkages across fields that are not typically examined together. Given the integrative aim of the paper, a narrative synthesis approach was adopted rather than a systematic review methodology. Articles were selected based on conceptual relevance to the three conceptual domains. The literature was analysed using an iterative thematic narrative synthesis approach informed by the principles of thematic analysis to generate initial themes.²⁸ Following article selection, studies were reviewed and grouped according to their primary conceptual focus. Through repeated reading and comparison of the literature, recurring concepts, areas of convergence, and theoretical linkages were identified and organised to generate five themes. These themes were subsequently synthesised to construct the conceptual model of post-shift diagnostic insight.

Results

A total of 31 references informed the narrative synthesis. The narrative synthesis generated five overlapping themes that informed the development of the conceptual model (Table 1). The most frequently represented themes were perceptual learning and expertise development, cognitive neuroscience of internally directed cognition, and clinical reasoning in imaging practice.

Discussion

Narrative synthesis and conceptual integration

From the initial three domains identified in the methodology, this review identified two convergent narratives across the literature: (1) clinical reasoning, perceptual expertise, and diagnostic error in imaging practice, shaped by cognitive load under high-demand conditions and (2) incubation, mind-wandering, and post-task cognitive processing. Although these themes are rarely examined together within radiography literature, their conceptual overlap provides a coherent explanatory framework that explains our proposed conceptual model for post-shift diagnostic insight.

Clinical reasoning, perceptual expertise, and diagnostic error in imaging practice

Diagnostic radiography requires the integration of perceptual skills and clinical judgement. Although radiographers are not responsible for issuing formal diagnostic reports in many jurisdictions, they routinely engage in evaluative tasks including image quality assessment, appraisal of positioning adequacy, trauma series decision-making, initial interpretation and escalation of unexpected findings. These tasks demand rapid visual pattern recognition alongside contextual clinical reasoning.²⁹

Research in medical image perception consistently demonstrates clear differences between novice and expert performance. Experts exhibit more efficient visual search strategies, reduced fixation on diagnostically irrelevant regions, and faster detection of abnormalities.²² Rather than relying solely on deliberate, step-wise analytical reasoning, experienced radiographers frequently employ non-analytical pattern recognition shaped by repeated exposure and case-based learning.²¹ This recognition-primed processing enables rapid interpretation in time-pressured environments; however, it is also susceptible to errors, particularly under conditions of high workload and cognitive fatigue. Errors frequently arise not from lack of knowledge, but from perceptual

Table 1
Summary of literature included in the narrative synthesis^a.

Themes	Key concepts explored	Number of sources
Clinical reasoning and diagnostic expertise in imaging	Clinical reasoning, image interpretation, pattern recognition, expertise development	8
Diagnostic error and cognitive load	Perceptual error, cognitive bias, workload, attentional limitations, working memory	7
Perceptual learning and expertise development	Visual expertise, perceptual learning, consolidation, adaptive expertise	10
Incubation and creative insight	Incubation, unconscious processing, creative problem solving, mind-wandering	7
Cognitive neuroscience of internally directed cognition	Default mode network, executive control network, associative processing, creative cognition	9

^a **Note:** Several references contributed to more than one theme and are therefore represented in multiple categories. Consequently, the number of sources reported across themes exceeds the total number of unique references included in the narrative synthesis.

oversight, satisfaction of search, anchoring bias, or cognitive overload.³⁰ In high-throughput environments, attentional resources are constrained. Continuous task engagement, time pressure, and workflow fragmentation may narrow perceptual bandwidth. Under such conditions, subtle findings may be overlooked or ambiguously encoded. Understanding the dual nature of perceptual expertise is therefore essential when examining how diagnostic insight may emerge beyond the immediate clinical encounter.

Cognitive load theory suggests that working memory capacity is limited,³¹ particularly when managing complex, multi-source information streams.³² Trauma imaging or multi-region examinations demand simultaneous attention to positioning accuracy, exposure factors, anatomical coverage, and patient stability. Executive control processes dominate in these contexts, applying differential weights to conflicting cues as a function of their perceived reliability.^{33,34} However, optimising for fast task completion, renders residual uncertainty (from incomplete perceptual encoding or unresolved interpretive ambiguity, for example²⁹) unavoidable after task termination. From a cognitive theory perspective, representations of a case may remain accessible to the DMN after the radiographer's shift, particularly if the case involved elevated uncertainty or ambiguity, or was emotionally evocative for the radiographer.³⁵ These residual representations provide fertile ground for subsequent post-event processing.

Expertise in visual diagnosis develops via perceptual learning.³⁶ Faster than the accumulation of explicit knowledge, perceptual learning is based on repeated exposure to a large number of diagnostic images.³⁷ The radiographer learns which features of an image are informative and how to extract that information efficiently. Unlike novices, who search scans systematically and effortfully, expert radiographers exhibit high levels of automaticity and quickly develop an impression of a scan (as pathological or not) within a second of first viewing it.^{38,39} Professional expertise does not rely on perceptual learning alone but integrates it with the clinical context and explicit knowledge, to optimise decision-making.⁴⁰ Importantly, however, error rates,

even for experts remain substantial when scans present with atypical cues.⁴¹

Perceptual learning is not limited to image viewing times, or even the longer time period over which many images are viewed within a clinical or training session. Consolidation during the days or weeks after image exposure strengthens perceptual learning, increasing its robustness to interference and generalisability.⁴² The relationship between incubation and consolidation is not fully understood. Important differences, for example consolidation benefits from sleep, which is not critical for incubation⁴³ preclude neural equivalence, but both rely on post-task processing outside of conscious awareness.^{36,44,45} Hence, post-shift processing during cognitively undemanding activities might facilitative both the long-term development as well as the shorter-term application of advanced diagnostic expertise.

Current radiography literature emphasises reflection, image critique, and feedback as mechanisms to improve diagnostic reasoning. However, little attention has been paid to how post-shift cognitive processing may continue beyond formal reflective structures. This is particularly important considering opportunities to undergo post-shift cognitive processing often far surpass the availability of more formal reflection activities. If perceptual learning and error recognition depend on integrating prior cases with emerging knowledge, it is plausible that low-demand post-shift states contribute to this consolidation. Viewing diagnostic reasoning as temporally extended rather than bounded within the imaging suite creates space to examine cognitive incubation as a mechanism underlying adaptive expertise.

Incubation, consolidation, and post-task cognitive processing

The incubation effect describes improved problem-solving performance following a period of disengagement from focused work.⁴ Rather than reflecting interruption or cognitive inactivity, incubation involves continued processing of previously encountered material outside conscious awareness.⁵ In a meta-analysis of incubation studies, Sio and Ormerod (2009) reported a reliable positive effect of breaks on subsequent problem-solving performance, particularly when the intervening task was undemanding.^{4,7} Low-demand contexts appear to facilitate diffuse associative processing via the DMN. Low cognitive load facilitates activity in the DMN, suppressing the executive control network, and thus permitting unconstrained associative restructuring of unresolved representations to occur. Creative insight occurs after a period of associative re-processing. The normally antagonistic DMN and executive control networks become jointly activated, allowing re-organised representations to reach conscious awareness.

Applying theories and neural models of incubation to diagnostic radiography offers a plausible account of post-shift insight. During imaging sessions, executive functions take precedence: radiographers focus on accurate positioning, initial imaging findings, efficient workflow, radiation safety, and patient care. In such scenarios, perceptual encoding tends to be quick and goal oriented. When faced with ambiguous cases or subtle findings, integration of conflicting cues may be incomplete or course and executed without thorough analysis. The sustained executive function required to maintain performance during a shift suppresses activity in the DMN, thereby preventing associative re-processing from taking place immediately, or in parallel with other work tasks.

Low-demand post-shift activities, such as commuting or engaging in routine tasks, may permit diffuse associative re-processing. Visual patterns, anatomical relationships, or contextual patient information encountered earlier in the day may be reorganised in relation to prior knowledge. The subjective experience of suddenly “remembering” a detail or reconsidering an

image interpretation may reflect conscious awareness at the completion of this restructuring process. In this sense, post-shift diagnostic insight is not a spontaneous occurrence detached from prior effort; it represents the integration of previously encoded material. Such integration is necessarily delayed as the high levels of executive control function needed during a shift suppress the DMN. Only once cognitive load is relieved can diffuse associative re-processing occur.

Diagnostic expertise develops through perceptual learning.^{29,40,46} Many exposures to relevant imagery facilitate the fast discovery of features with diagnostic relevance and the efficient extraction of information from such features. Perceptual learning relies heavily on consolidation: an extended process of post-viewing cognitive processing which can last days or even weeks. Like incubation, consolidation relies on the DMN, a network that is necessarily suppressed by the cognitively demanding tasks of a radiographer's normal shift. Therefore, both the neural basis of consolidation and its protracted timescale necessarily place it outside formal reflective practice.

Viewing post-shift diagnostic insight through the lens of incubation reframes it from an anecdote to a cognitive process. This suggests that clinical reasoning may extend beyond the imaging encounter. Similarly, consolidation processes that are integral to the development of diagnostic expertise necessarily occur long after the training or clinical experiences that give rise to them.

Integrative synthesis: a conceptual model of post-shift diagnostic insight

The preceding sections outlined two convergent narratives: the cognitive demands of diagnostic radiography, empirical evidence on incubation and associative processing, and the role of perceptual expertise in imaging interpretation. Integrating these domains supports a conceptual model in which post-shift diagnostic insight is an inevitable epiphenomenon, when perceptual experts are forced to make complex decisions under time pressure and high cognitive load. It should be noted that the proposed model is theoretical and requires empirical validation through neuro-imaging studies or ‘think-aloud’ protocols conducted post-shift.

Conceptually, post-shift diagnostic insight can be understood as the interaction of three elements¹: cognitively demanding clinical engagement that loads complex representations,² low-demand post-task states that permit associative restructuring, and³ re-engagement of executive evaluation when insight becomes conscious. This process aligns with broader cognitive models of creativity and expertise development while remaining grounded in the realities of imaging practice (Fig. 1). This model reframes post-shift diagnostic insight as a temporally extended phase of clinical reasoning rather than an isolated reflective act. Insight may manifest as sudden recall of an anatomical concern, potentially missed pathology, reconsideration of exposure parameters, or recognition that a view could have been repeated. Importantly, such insight does not merely imply an opportunity for delayed error correction. It may also reflect ongoing consolidation of perceptual learning: increasing the accuracy of recent judgements and strengthening future discrimination of similarly subtle findings. In this sense, post-shift processing builds adaptive expertise, defined as the capacity to refine performance through the continual integration of experience, rather than reliance solely on routine execution.⁴⁷

Implications for clinical practice, education, and workforce sustainability

Understanding post-shift diagnostic insight as an extension of clinical reasoning carries implications for practice, professional

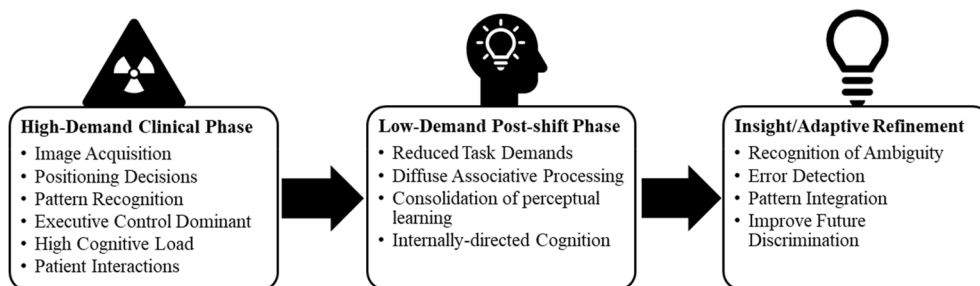


Figure 1. Consolidation model of post-shift diagnostic insight in diagnostic radiography.

development, and workforce design. The temporal extension of diagnostic reasoning across and beyond the clinical shift is illustrated in Fig. 2. Recognising diagnostic reasoning as temporally extended beyond the imaging suite invites practical and organisational responses. Structured mechanisms that acknowledge this component as integral to professional expertise may strengthen both performance and wellbeing.

Clinical practice and error recognition

Our model has implications for diagnostic error mitigation. Diagnostic error in imaging is multifactorial and frequently attributed to perceptual oversight, cognitive bias, or workflow pressure.³⁰ In diagnostic radiography, mitigation efforts primarily target technical accuracy through protocol standardisation, structured image evaluation, supervised feedback, simulation-based rehearsal, and continuing professional development. While not a substitute for these formal quality assurance processes, the present synthesis suggests that consolidation of perceptual learning and ongoing integration of new patterns likely occurs outside formal professional training and review. Acknowledging this extended reasoning phase expands understanding of how radiographers learn from borderline or uncertain cases.

Encouraging radiographers to attend to spontaneous post-shift insights, and to recognise their integral role in expertise-driven decision-making may help maximally profit from professional development opportunities. For example, creating psychologically safe mechanisms for radiographers to revisit cases the following

day, without judgement, may enhance adaptive expertise, reduce errors and enhance patient safety. Informal review opportunities could incorporate space for “retrospective clarity” discussions. Rather than framing delayed recognition as failure, it can be positioned as a normal and valuable feature of professional cognition. Such practices align with safety science principles that encourage learning from near-miss events and borderline cases.⁴⁸

Education and reflective practice

Radiography education frequently promotes structured reflection, image critique exercises, and simulation-based rehearsal. Hence, reflection is often conceptualised as a deliberate, conscious activity confined to scheduled sessions. Post-shift insight, supported by incubation and the ongoing consolidation and integration of new perceptual patterns, suggests that substantive reflective gains occur outside formal reflection periods. Educational strategies might therefore incorporate strategic spacing between sessions, to facilitate consolidation and incubation, especially where complex cases are concerned.

Providing delayed, post-simulation training opportunities for students to articulate and discuss insights that emerge after a session, rather than only during it, will help students recognise the value of post-shift insights. Educating students about the cognitive and neural mechanisms that support post-shift insights, may assist appreciation of the important role that cognitive downtime plays in their professional reasoning. Educating radiographers about high and low cognitive demands, and mechanisms of consolidation and incubation may also reduce the anxiety associated with delayed clarity and remove focus on errors as a sign of deficiency.

Workforce wellbeing and cognitive recovery

Workforce models that permit protected downtime between high-intensity imaging sessions may support both performance and workforce sustainability. Radiography is characterised by high throughput, time pressure, and frequent task switching.^{49,50} Sustained executive control without adequate recovery risks attentional fatigue and burnout and increases the likelihood of clinician error.^{51,52} From a cognitive perspective, low-demand states are not merely restorative but potentially generative. Allowing dedicated time and space for cognitive disengagement may therefore contribute to both expertise refinement, with improved imaging and patient outcomes, and to improved clinician wellbeing, with a reduction in the risk of professional burnout.⁵³

Workforce wellbeing and sustainability gains may be achieved through closer alignment of institutional structures with cognitive architecture. While organisational constraints remain real, even modest adjustments in shift design (timing), or debriefing structure may yield desirable outcomes. Acknowledging the extended

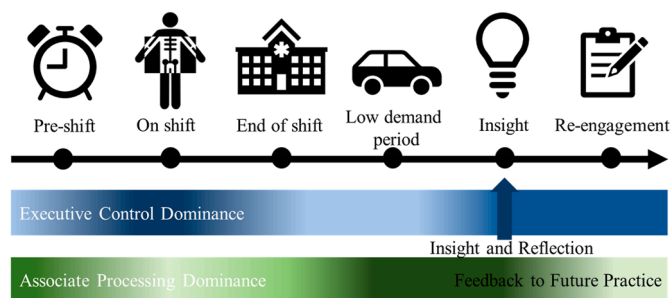


Figure 2. Temporal extension of diagnostic reasoning across and beyond the clinical shift. The intensity of colour within each bar represents the relative dominance of the cognitive network at different stages of the work cycle. Executive Control Network (ECN) activity increases during active clinical work, reflecting sustained attention, technical execution, and decision making under cognitive load. ECN dominance is highest during the clinical shift and decreases during low-demand periods after work. In contrast, Default Mode Network (DMN) activity is reduced during high-demand clinical tasks and increases during post-shift low-demand states. During these periods of reduced external cognitive demand, associative processing and memory integration may occur. The point of insight represents the moment when reorganised representations reach conscious awareness and executive evaluation is re-engaged.

nature of diagnostic reasoning, and, consequently, mitigating unrealistic expectations of immediate productivity will lessen immediate proximate pressures during the shift. Reducing digital interruptions post-shift, by encouraging workers to disconnect and quarantine their personal time from the cognitive challenges of their professional life is predicted to promote workforce sustainability through a healthy work-life balance, and promote the conditions most conducive to associative re-processing, incubation, and insight supporting better professional performance and more sustainable workforce wellbeing.

Directions for future research

A key limitation of the present conceptual model is that it extrapolates findings from cognitive neuroscience, creativity research, and incubation theory to diagnostic radiography practice. While evidence from these fields suggests that interactions between the DMN and executive control networks may support associative processing, insight generation, and learning consolidation, no neuroimaging studies have directly examined these mechanisms in radiographers. Consequently, references to DMN involvement in post-shift diagnostic insight should be interpreted as theoretically informed propositions rather than empirically established phenomena within diagnostic radiography. Empirical research within diagnostic radiography is needed to examine post-shift diagnostic insight systematically. Reflection is widely recognised as central to expertise development in health professions education,^{21,54} yet its temporal dimensions remain underexplored within imaging practice. Investigation of the implementation and impact of structured post shift review sessions should also be explored. Examining how radiographers interpret and act upon insights that arise after a shift may clarify whether post-shift associative re-processing contributes to adaptive expertise more so, less so, or in different ways to retrospective rumination.

Conclusions

Post-shift diagnostic insight in diagnostic radiography can be conceptualised as the outcome of extended clinical reasoning beyond the immediate imaging encounter. Evidence from perceptual expertise and diagnostic error research, combined with incubation theory supports a model in which high-demand executive engagement during the shift, is followed by associative re-processing, during low-demand post-shift activities. Under this model, insights that emerge after a shift reflect continued restructuring of partially encoded or ambiguous cases below the level of conscious awareness and are not attributable to delayed reflection alone. Recognising the extended temporal dimension of complex clinical decision-making reframes post-shift clarity as a feature of high-level professional cognition, not a sign of deficient performance during a shift. Aligning clinical practice, education, and workforce design with the cognitive architecture of clinical expertise may strengthen adaptive performance, support error recognition, and contribute to sustainable radiography practice.

Ethics approval and consent to participate

N/A.

Availability of data

N/A.

Author contributions

MC: Project Administration, Conceptualisation, methodology, validation, investigation, writing – original draft.
 SW: methodology, writing – review & editing.
 BO: methodology, writing – review & editing.
 JA: methodology, writing – review & editing.
 KBS: methodology, writing – review & editing.
 HK: methodology, writing – review & editing.
 FG: methodology, writing – review & editing.
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Generative AI use

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Conflict of interest statement

The authors declare that they have no competing interests.

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References

- Kennedy TJ, Regehr G, Baker GR, Lingard L. Preserving professional credibility: grounded theory study of medical trainees' requests for clinical support. *BMJ*. 2009;338.
- Ramlal A, Duncan D, Alltree J. The meaning of critical thinking in diagnostic radiography. *Radiography*. 2021;27(4):1166–1171.
- Pieterse T, Temane A, Downing C. A model to facilitate critical thinking of radiography students. *J Med Radiat Sci*. 2023;70(4):369–379.
- Sio UN, Ormerod TC. Does incubation enhance problem solving? A meta-analytic review. *Psychol Bull*. 2009;135(1):94–120.
- Ritter SM, Dijksterhuis A. Creativity—the unconscious foundations of the incubation period. *Front Hum Neurosci*. 2014;8:215.
- Embrey JR, Donkin C, Newell BR. Is all mental effort equal? The role of cognitive demand-type on effort avoidance. *Cognition*. 2023;236:105440.
- Baird B, Smallwood J, Mrazek MD, Kam JWY, Franklin MS, Schooler JW. Inspired by distraction: mind wandering facilitates creative incubation. *Psychol Sci*. 2012;23(10):1117–1122.
- Leszczynski M, Chaieb L, Reber TP, Derner M, Axmacher N, Fell J. Mind wandering simultaneously prolongs reactions and promotes creative incubation. *Sci Rep*. 2017;7(1):10197.
- Brodt S, Pöhlchen D, Täumer E, Gais S, Schönauer M. Incubation, not sleep, aids problem-solving. *Sleep*. 2018;41(10):zsy155.
- Gilhooly KJ, Georgiou G, Devery U. Incubation and creativity: do something different. *Think Reas*. 2013;19(2):137–149.
- Posner MI, Petersen SE. *The attention system of the human brain*. 1989.
- Raichle ME, MacLeod AM, Snyder AZ, Powers WJ, Gusnard DA, Shulman GL. A default mode of brain function. *Proc Natl Acad Sci*. 2001;98(2):676–682.
- Buckner RL, Andrews-Hanna JR, Schacter DL. The brain's default network. *Ann N Y Acad Sci*. 2008;1124(1):1–38.
- Norman DA, Shallice T. Attention to action: willed and automatic control of behavior. In: *Consciousness and self-regulation: Advances in research and theory* volume 4.
- Bressler SL, Menon V. Large-scale brain networks in cognition: emerging methods and principles. *Trends Cognit Sci*. 2010;14(6):277–290.
- Seeley WW, Menon V, Schatzberg AF, Keller J, Glover GH, Kenna H, et al. Dissociable intrinsic connectivity networks for salience processing and executive control. *J Neurosci*. 2007;27(9):2349–2356.
- Andrews-Hanna JR, Smallwood J, Spreng RN. The default network and self-generated thought: component processes, dynamic control, and clinical relevance. *Ann N Y Acad Sci*. 2014;1316(1):29–52.
- Dwyer DB, Harrison BJ, Yücel M, Whittle S, Zalesky A, Pantelis C, et al. Large-scale brain network dynamics supporting adolescent cognitive control. *J Neurosci*. 2014;34(42):14096–14107.
- Beatty RE, Benedek M, Barry Kaufman S, Silvia PJ. Default and executive network coupling supports creative idea production. *Sci Rep*. 2015;5(1):10964.

20. Beaty RE, Benedek M, Silvia PJ, Schacter DL. Creative cognition and brain network dynamics. *Trends Cognit Sci*. 2016;20(2):87–95.
21. Norman G, Young M, Brooks L. Non-analytical models of clinical reasoning: the role of experience. *Med Educ*. 2007;41(12):1140–1145.
22. Kundel HL, Nodine CF, Conant EF, Weinstein SP. Holistic component of image perception in mammogram interpretation: gaze-tracking study. *Radiology*. 2007;242(2):396–402.
23. Limchareon S, Kongpromsuk S. The value of medical student radiology education: a comparison of 1-week, 2-week, electives, and compulsories. *J Chin Med Assoc*. 2018;81(6).
24. Wright C, Reeves P. Image interpretation performance: a longitudinal study from novice to professional. *Radiography (Lond)*. 2017;23(1):e1–e7.
25. Ofori-Manteaw BB, Dzidzornu E. Accuracy of appendicular radiographic image interpretation by radiographers and junior doctors in Ghana: can this be improved by training? *Radiography*. 2019;25(3):255–259.
26. Goldstone RL. Perceptual learning. *Annu Rev Psychol*. 1998;49(1):585–612.
27. Akudjedu T, Ago J, Iweka E, Dushimirimana S. Evidence synthesis strategies and indications for scoping and systematic reviews: a methodological guide and recommendations for radiography research. *Radiography*. 2026;32(1):103238.
28. Braun V, Clarke V. Thematic analysis. In: *A practical guide*. Thousand Oaks, CA: Sage; Publications; 2022.
29. Krupinski EA. Current perspectives in medical image perception. *Atten Percept Psychophys*. 2010;72(5):1205–1217.
30. Waite S, Scott J, Gale B, Fuchs T, Kolla S, Reede D. Interpretive error in radiology. *Am J Roentgenol*. 2017;208(4):739–749.
31. Sweller J. Cognitive load during problem solving: effects on learning. *Cogn Sci*. 1988;12(2):257–285.
32. Oberauer K, Farrell S, Jarrold C, Lewandowsky S. What limits working memory capacity? *Psychol Bull*. 2016;142(7):758.
33. Braem S, Bugg JM, Schmidt JR, Crump MJ, Weissman DH, Notebaert W, et al. Measuring adaptive control in conflict tasks. *Trends Cognit Sci*. 2019;23(9):769–783.
34. Jacobs RA. Optimal integration of texture and motion cues to depth. *Vis Res*. 1999;39(21):3621–3629.
35. Rachman S. Emotional processing, with special reference to post-traumatic stress disorder. *Int Rev Psychiatr*. 2001;13(3):164–171.
36. Waite S, Grigorian A, Alexander RG, Macknik SL, Carrasco M, Heeger DJ, et al. Analysis of perceptual expertise in radiology—current knowledge and a new perspective. *Front Hum Neurosci*. 2019;13:213.
37. Alexander RG, Waite S, Macknik SL, Martinez-Conde S. What do radiologists look for? Advances and limitations of perceptual learning in radiologic search. *J Vis*. 2020;20(10):17.
38. Brennan PC, Gandomkar Z, Ekpo EU, Tapia K, Trieu PD, Lewis SJ, et al. Radiologists can detect the ‘gist’ of breast cancer before any overt signs of cancer appear. *Sci Rep*. 2018;8(1):8717.
39. DiGirolamo GJ, DiDominica M, Qadri MA, Kellman PJ, Krasne S, Massey C, et al. Multiple expressions of “expert” abnormality gist in novices following perceptual learning. *Cogn Res Princ Implic*. 2023;8(1):10.
40. Waite S, Farooq Z, Grigorian A, Siström C, Kolla S, Mancuso A, et al. A review of perceptual expertise in radiology—how it develops, how we can test it, and why humans still matter in the era of artificial intelligence. *Acad Radiol*. 2020;27(1):26–38.
41. Lee CS, Nagy PG, Weaver SJ, Newman-Toker DE. Cognitive and system factors contributing to diagnostic errors in radiology. *Am J Roentgenol*. 2013;201(3):611–617.
42. Yotsumoto Y, Sasaki Y, Chan P, Vasios CE, Bonmassar G, Ito N, et al. Location-specific cortical activation changes during sleep after training for perceptual learning. *Curr Biol*. 2009;19(15):1278–1282.
43. Karni A, Tanne D, Rubenstein BS, Askenasy JJ, Sagi D. Dependence on REM sleep of overnight improvement of a perceptual skill. *Science*. 1994;265(5172):679–682.
44. Beaty RE, Benedek M, Kaufman SB, Silvia PJ. Default and executive network coupling supports creative idea production. *Sci Rep*. 2015;5:10964.
45. Beaty RE, Benedek M, Silvia PJ, Schacter DL. Creative cognition and brain network dynamics. *Trends Cogn Sci*. 2016;20(2):87–95.
46. Norman G, Coblenz C, Brooks L, Babcock C. Expertise in visual diagnosis: a review of the literature. *Acad Med*. 1992;67(10):S78–S83.
47. Jensen RD, Brydges R, Grierson L. Re-examining the integration of routine and adaptive expertise: there is no such thing as routine from a motor control perspective. *Adv Health Sci Educ*. 2022;27(5):1283–1291.
48. Gnoni MG, Saleh JH. Near-miss management systems and observability-in-depth: handling safety incidents and accident precursors in light of safety principles. *Saf Sci*. 2017;91:154–167.
49. Alexander R, Waite S, Bruno MA, Krupinski EA, Berlin L, Macknik S, et al. Mandating limits on workload, duty, and speed in radiology. *Radiology*. 2022;304(2):274–282.
50. Chau MT, Spuur KM, Vu H. Health human resources shortages in radiography and sustainable workforce development in Australia. *Radiography*. 2026;32(2).
51. Winefield AH, Gillespie N, Stough C, Dua J, Hapuarachchi J, Boyd C. Occupational stress in Australian university staff: results from a national survey. *Int J Stress Manag*. 2003;10(1):51.
52. Kinman G, Wray S. Well-being in academic employees—a benchmarking approach. In: *Handbook of research on stress and well-being in the public sector*. Edward Elgar Publishing; 2020:152–166.
53. Kennedy E, Ryan M, England A, Sarkodie B, Khine R, McEntee MF. High workload and under-appreciation lead to burnout and low job satisfaction among radiographers. *Radiography*. 2025;31(1):231–240.
54. Mann K, Gordon J, MacLeod A. Reflection and reflective practice in health professions education: a systematic review. *Adv Health Sci Educ*. 2009;14(4):595–621.