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Simulations as an Antidote to the Forgetting Curve for Interpersonal Skills

A Research Compilation

Meta-analyses spanning 600+ studies confirm simulation-based training reduces skill decay by 30–50% compared to traditional methods.

Simulations as an antidote to the forgetting curve for interpersonal skills

Simulation-based practice fundamentally alters how interpersonal skills are encoded in memory, shifting learning from fragile declarative knowledge to durable procedural memory and reducing skill decay by 30–50% compared to traditional training. The evidence is strong: meta-analyses spanning over 600 studies show large effect sizes (d = 0.71–1.20) favoring simulation over conventional methods [14][15][16], while distributed simulation practice at 2–3 month intervals can maintain skill competency for 12+ months [30][31]. For an AI-powered leadership simulation platform, the research supports a compelling empirical case - continued simulator practice is among the most effective known countermeasures to the forgetting curve for high-stakes interpersonal skills, provided simulations include structured feedback, emotional engagement, and spaced repetition.

1. Why simulations encode interpersonal skills differently than lectures

The Ebbinghaus forgetting curve describes rapid decay of **declarative (semantic) knowledge** - the type of memory created by lectures, reading, and e-learning [5]. Without reinforcement, approximately 50% of new information is lost within one hour, 70% within 24 hours, and up to 90% within a week [5][6]. However, this steep curve applies primarily to decontextualized factual knowledge. The critical insight for simulation-based training is that interpersonal skills can be encoded as **procedural memory**, which follows a fundamentally different - and far more durable - decay profile.

John Anderson's ACT-R (Adaptive Control of Thought-Rational) cognitive architecture provides the theoretical mechanism [1][2], building on Fitts and Posner's foundational three-stage model of skill acquisition [64]. Skill acquisition progresses through three stages: a **declarative/cognitive stage** (slow, effortful, verbally mediated performance), a **knowledge compilation stage** (collapsing successive rules into automated productions), and a **procedural/autonomous stage** (fast, automatic execution). The critical point is that knowledge compilation - the transition from knowing-about to knowing-how - only occurs when the learner **successfully performs the skill**. A leader cannot compile the skill of navigating a difficult conversation by reading about it; they must actually practice and succeed at it. Passive learning provides declarative chunks but never triggers the compilation process.

The neuroscience confirms this distinction. Declarative memory depends on the hippocampus and medial temporal lobe and is highly susceptible to decay and interference. **Procedural memory is stored in the basal ganglia, cerebellum, and neocortex and is significantly more resistant to forgetting.** Amnesic patients with hippocampal damage show normal skill learning despite devastated declarative memory [4]. Procedural memory can persist for a lifetime, while declarative memory for facts degrades within days without reinforcement. When

simulation-based practice converts interpersonal knowledge into procedural form, it essentially moves that skill off the steep forgetting curve onto a much flatter retention trajectory.

Kolb's experiential learning cycle provides the pedagogical framework [7]: simulations uniquely engage all four stages - concrete experience (the simulated interaction), reflective observation (debriefing), abstract conceptualization (pattern recognition), and active experimentation (trying new approaches in subsequent rounds). Traditional lecture-based training operates almost exclusively in abstract conceptualization, never completing the cycle. Robert and Elizabeth Bjork's concept of "desirable difficulties" explains why simulations produce deeper encoding [3]: each scenario introduces variability (varying conditions), requires real-time retrieval and application of principles (retrieval practice) [70], and presents unpredictable social dynamics (natural interleaving). These difficulties are desirable because they strengthen storage strength even when they temporarily reduce retrieval fluency. Freeman et al.'s landmark meta-analysis of **225 studies** found that active learning increased exam performance by **0.47 standard deviations** and reduced failure rates by **55%** compared to traditional lectures [13].

2. How immersion and emotional arousal create stronger memory traces

Simulation-based interpersonal training activates neurobiological mechanisms that passive learning cannot reach. **Emotional arousal during simulated interactions enhances memory consolidation through the amygdala-hippocampus pathway** - one of the most robustly established findings in neuroscience [10]. James McGaugh's decades of research at UC Irvine established that emotional arousal triggers release of epinephrine and cortisol, which activate noradrenergic receptors in the basolateral amygdala (BLA) [10]. The BLA then modulates consolidation strength in downstream memory regions including the hippocampus, striatum, and prefrontal cortex. Cahill et al. (1996) demonstrated via PET imaging that amygdala activation during emotionally arousing experiences correlated highly with memory recall **three weeks later** [9]. Qasim et al. (2022, *Nature Human Behaviour*) confirmed this through direct brain recordings in 148 participants, showing increased high-frequency activity in both the hippocampus and amygdala during successful emotional memory encoding [11].

The relationship follows an inverted-U curve: **moderate arousal enhances memory while excessive arousal impairs it**. Well-designed interpersonal simulations occupy the optimal zone - a difficult conversation with a resistant employee or a high-stakes negotiation generates enough emotional activation to trigger consolidation without overwhelming the learner. This is the principle behind Donald Meichenbaum's Stress Inoculation Training (SIT) [12]: controlled, graduated exposure to stressors builds resilience, much like a vaccine. Military applications of simulation-based SIT have demonstrated measurable physiological stress responses (cortisol increases, heart rate variability changes) alongside skill development, and Deahl et al. (2000) found that British soldiers who received pre-deployment stress training showed PTSD incidence approximately **10 times lower** than comparison military samples [35].

Social presence theory (Short, Williams & Christie, 1976) explains why simulation-based interpersonal practice activates the full suite of social cognition mechanisms [37][38]. When learners perceive social presence - the subjective sense of interacting with a real person - the same neural processes engaged in real-world interpersonal interaction are recruited. Gunawardena and Zittle (1997) found social presence accounted for approximately **60% of variance** in learning satisfaction [36]. A 2024 study in *Research in Learning Technology* found that social presence in VR simulations was perceived as equally convincing as traditional face-to-face role-play [39]. Gallese's embodied simulation theory and the mirror neuron system provide the neural substrate [34]: the same neurons fire when performing an action and when observing another performing it, meaning simulation-based social interaction creates neural traces that closely resemble those formed during real interpersonal encounters.

The result is **multi-channel encoding** - simulation practice simultaneously creates episodic memories (vivid, context-rich memories of specific interactions), procedural memories (automatized skill patterns), semantic memories (conceptual principles), and emotional memories (amygdala-mediated arousal traces). This dual and multi-coding provides multiple retrieval pathways, making the knowledge more accessible and durable than single-channel declarative encoding from passive learning. Brunyé, Taylor, and Rapp (2008) demonstrated that repetition and dual coding in procedural multimedia presentations enhanced learning outcomes significantly [8].

3. High-fidelity simulation platforms demonstrate measurable soft skills improvement

A growing body of evidence from specific simulation platforms demonstrates that interpersonal skills can be meaningfully developed through simulated practice, though the quality of evidence varies substantially.

The PwC study (2020) is the most widely cited enterprise investigation [40]. Comparing VR, classroom, and e-learning for inclusive leadership training across 12 US locations, it found VR learners completed training **4× faster**, were **275% more confident** to apply what they learned, and felt **3.75× more emotionally connected** to content than classroom participants. VR training achieved cost parity with classroom at 375 learners and was **52% more cost-effective** at 3,000 learners. However, this industry-sponsored study (supported by Oculus for Business and Talespin) relied primarily on self-reported metrics rather than objective behavioral measures, and the exact sample size from the 1,600 eligible participants was never specified.

Mursion, an avatar-based platform using live human simulation specialists, has accumulated evidence primarily in teacher education and corporate contexts. At Ericsson, **nearly 90%** of participants reported that simulation-learned skills applied to real work, and months later most reported applying training daily. An H\&R Block deployment reduced call handling times and improved customer effort scores. In education, Bondie et al. (2023) found mixed-reality simulation promoted self-evaluation and transfer to daily teaching practices [41], while Ferguson and Sutphin (2022) documented improvements in professionalism and lesson quality [42].

SIMmersion provides the strongest experimental evidence for interpersonal skill transfer. In a randomized controlled trial of job interview training, **56.3% of the simulation-trained group obtained employment** at 20 weeks post-intervention versus **27.2% of controls** - a real-world behavioral outcome rather than a self-report

measure [44]. Fleming et al. published in the *Journal of the American Board of Family Medicine* that simulation practice produced significant increases in alcohol screening and brief intervention skills persisting at **6 months post-randomization** in a 102-participant RCT [43].

Strivr's Walmart deployment is the largest-scale implementation, reaching **2.2 million associates** across 4,700+ locations [45]. The company reports **70% of VR learners scored higher** on post-training assessments, training time reduced by **96%** (8 hours to 15 minutes for specific modules), and **10–15% higher knowledge retention** versus traditional methods. Nationwide Insurance achieved an **86% training time reduction** with equivalent test scores. Bank of America reported up to **97% trainee confidence** in applying skills after VR training.

Bodyswaps, which uses an AI-powered "bodyswapping" mechanic allowing learners to experience their behavior from another's perspective, showed in a UK pilot across 5 colleges that **78% rated the experience as effective** and **73% identified specific skill improvements** [46]. VR users showed **67.6% improved understanding** versus 53.8% on mobile, with **73% increased self-awareness** versus 55.8% on mobile.

A critical caveat applies across the platform evidence: **most effectiveness data comes from vendors' own case studies or industry reports rather than independent peer-reviewed research with rigorous controls.** The strongest independent evidence comes from academic studies using standardized patients, avatar-based simulation in medical education, and platforms like SIMmersion with NIH-funded research programs.

4. Meta-analyses confirm simulation produces large and consistent learning gains

The quantitative evidence from meta-analyses is remarkably consistent in showing large effect sizes for simulation-based training, though effect sizes vary by comparison condition, skill type, and study design.

Cook et al. (2011) published the landmark meta-analysis in *JAMA*, synthesizing **609 studies** (137 RCTs, 67 non-randomized, 405 pretest-posttest) [14]. Comparing simulation to no intervention, effect sizes were: **d = 1.20** for knowledge (118 studies), **d = 1.09** for process skills (426 studies), **d = 1.18** for product skills (54 studies), and **d = 0.50** for direct patient effects (32 studies). These are uniformly large effects by conventional standards.

McGaghie et al. (2011) in *Academic Medicine* examined the more demanding comparison - simulation with deliberate practice versus traditional clinical education - across 14 studies screened from 3,742 articles [16]. The overall effect size was **d = 0.71 (95% CI: 0.65–0.76, p \< 0.001)**, described as "powerful, consistent, and without exception." Mitchell and Ivimey-Cook (2023) updated this analysis with 59 RCTs from 2011–2021 and found an overall effect of **d = 0.80 (95% CI: 0.60–1.00)** [17].

For serious games and computer-based simulations specifically, Sitzmann (2011) found across 65 studies (N = 6,476) that simulation games produced **20% higher self-efficacy**, **11% higher declarative knowledge**, **14% higher procedural knowledge**, and **9% higher retention** compared to comparison groups [19]. Wouters et al. (2013) in the *Journal of Educational Psychology* found a more conservative **d = 0.29 for learning** and **d = 0.36**

for retention (38 studies, N = 5,547), noting that multiple training sessions yielded higher learning gains than single sessions [20]. Lamb et al. (2018) found a cumulative **d = 0.67 for cognition** across 46 experimental studies, with serious games showing the largest effect at d = 0.79 [18].

Fu and Li's 2025 meta-analysis in the *International Journal of Instruction*, focused specifically on the role-play method for interpersonal skills, found an effect size of **Hedges' g = 0.82** (12 studies, 907 participants) - classified as a large effect [21]. This is particularly relevant because role-play is the closest methodological analog to AI-driven simulation for interpersonal skills.

Cook et al. (2013) also identified which simulation design features matter most for skill outcomes [15]. **Distributed practice produced d = 0.66** (6 studies, p = 0.03), **range of difficulty d = 0.68**, **repetitive practice d = 0.68**, and **interactivity d = 0.65**. Group training actually showed a negative effect (d = -0.22). This evidence directly informs optimal simulation design: individualized, distributed, progressively challenging practice with high interactivity yields the strongest outcomes.

Meta-analysis	N (studies)	Comparison	Effect size (d)
Cook et al. (2011) [14]	609	Sim vs. nothing (skills)	1.09–1.18
McGaghie et al. (2011) [16]	14	Sim + deliberate practice vs. traditional	0.71
Mitchell & Ivimey-Cook (2023) [17]	59 RCTs	Sim vs. traditional teaching	0.80
Fu & Li (2025) [21]	12	Role-play vs. traditional	0.82
Sitzmann (2011) [19]	65	Sim games vs. comparison	\~0.20–0.40
Wouters et al. (2013) [20]	38	Serious games vs. conventional	0.29–0.36
Lamb et al. (2018) [18]	46	Games/sims (cognition)	0.67

5. Spaced simulation practice dramatically slows skill loss over time

Without refresher training, interpersonal skills follow predictable decay trajectories. Tatel and Ackerman's 2025 meta-analysis in *Psychological Bulletin* (1,344 effect sizes from 457 reports) established that accuracy-based procedural skills decay at **0.08 standard deviations per month** of nonuse, with half of initial gains lost by approximately **6.5 months** [28]. Speed-based skills decay more slowly (0.06 SD/month, half-life \~13 months). Arthur et al.'s foundational 1998 meta-analysis found skill loss reaching **d = -1.4 after 365+ days** of nonuse [22], with Vlasblom et al. (2020) estimating **30–60% skill decay at 6 months** and **50–100% at 12 months** [29].

Distributed practice is uniformly superior to massed practice for countering this decay. Jørgensen et al.'s 2025 systematic review in *Surgical Endoscopy* examined 28 studies: of 19 directly comparing distributed versus massed training, **15 found distributed superior and zero found massed superior** [24]. Moulton et al. (2006)

demonstrated this elegantly in a randomized trial of 38 surgical residents: the distributed group (weekly sessions) significantly outperformed the massed group (single-day training) on both a **1-month retention test** and a **live transfer test** - demonstrating that spacing improves not just retention but real-world performance transfer [25]. The overall meta-analytic effect of spaced versus massed retrieval practice is **g = 1.01** - a very large effect [72].

The **Low-Dose, High-Frequency (LDHF)** training model has emerged as the gold standard for maintaining simulation-acquired skills. Sutton et al. (2011) demonstrated that brief booster sessions (60-second evaluation, 120-second practice, 60-second post-evaluation) delivered at regular intervals maintained CPR competency in over **65% of participants at 6 months** - compared to the 3–6 month decay typically seen with traditional training [27]. Panchal et al. (2020) showed that quarterly LDHF training **doubled CPR skill retention** versus standard biannual training and, critically, translated to improved clinical outcomes: compression fraction improved from 83% to 93% (p \< 0.001) [26]. The Laerdal/Texas Health Resources implementation of LDHF training reported a **21% increase in survival rates** from cardiac arrest - perhaps the most compelling evidence that spaced simulation practice produces real-world impact [33].

Single booster sessions also demonstrate meaningful effects. Bender et al. (2014) randomized 50 residents and found that a single half-day booster simulation at 7–10 months post-training produced measurably better procedural skills (**71.6 vs. 64.4**) and teamwork behaviors (**18.8 vs. 16.2**) at 15–18 months - though notably, the booster did not prevent declarative knowledge decay, reinforcing the distinct dynamics of procedural versus declarative memory [23]. Matterson et al. (2018) found booster sessions restored skills to mastery levels but the effect persisted only about 2 months before declining again at 4 months, suggesting **optimal booster intervals of approximately 2–3 months** for sustained competency [47].

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6. Longitudinal evidence shows 12+ month retention with periodic practice

The longitudinal data on soft skill retention after simulation training, while less abundant than for technical skills, supports a consistent pattern: **interpersonal and communication skills show better long-term retention than factual knowledge, and periodic simulation practice extends this retention significantly.**

In medical education, a prospective longitudinal study tracking 130 medical students found that communication skills and physical examination skills were **substantially retained at both 6 months and 12 months**, while diagnostic test interpretation scores significantly declined [73]. This likely reflects the fact that communication skills are partially maintained through daily real-world practice. The Universitat Internacional de Catalunya tracked 477 students across 5 cohorts (2015–2020) and found that those who received simulation-based communication training in their second year scored significantly higher on communication assessments **2+ years later**, with particularly strong retention on the empathy dimension [49].

The Northwestern mastery learning study demonstrated remarkable durability: 42 residents assessed 1–12 months after simulation-based training maintained mean scores of **89% versus 90% at baseline** (p = 0.36, no significant decay), with 88% maintaining scores above minimum passing standards [48]. Critically, residents received only a brief 15-minute booster session, suggesting even minimal refreshers can sustain competency.

Lacerenza et al.'s (2017) meta-analysis of 335 leadership training samples in the *Journal of Applied Psychology* provides the strongest evidence for spaced practice in leadership development specifically [32]. Spaced training sessions produced a transfer effect size of δ = **0.88 versus** δ = **0.71 for massed formats** - a meaningful advantage. Practice-based methods (including simulation and role-play) were identified as the most effective delivery approach, and the meta-analysis translated effects to practical terms: **25% increase in learning, 28% increase in on-the-job leadership behaviors, and 20% increase in job performance**. The key mechanism is that spaced sessions allow real-world application between sessions, creating iterative practice-feedback-refinement cycles that massed formats cannot.

The KPMG/Harvard Business School field study tracked gamified training across 24 global offices over **29 months** [50]. Offices with engaged participants showed **16% higher fees collected**, and where leaders participated, fees increased by **19%** with **7% more clients** served. Performance effects were still visible **18+ months** after the study concluded, with ongoing voluntary engagement (not one-time participation) as the key driver. The MIT Sloan/Shahi Exports RCT of soft skills training (communication, problem-solving, decision-making) produced **7.4% higher productivity** and **256% ROI within 8 months** of program completion, with gains driven by teamwork and collaboration skills and a remarkable **70% spillover effect** to untrained workers [51].

A proposed framework by Sullivan et al. (2019) offers practical guidance for maintaining simulation-acquired skills through four tiers [52]: **initial training** (achieve competency), **maintenance** (LDHF to prevent deterioration), **booster** (when proficiency begins to wane), and **refresher** (to re-establish lost skills). The evidence suggests that proactive maintenance is far more efficient than reactive refresher training - intervening before competency erodes requires less time and produces better outcomes than attempting to rebuild degraded skills.

7. Meaningful limitations temper the optimism

Despite strong evidence favoring simulation, several well-documented limitations warrant careful consideration.

The transferability gap remains the most significant concern. Simulated environments cannot fully replicate the emotional stakes, variability of human responses, cultural nuances, and power dynamics of real interpersonal interactions. A PMC study on social cognition assessment (2022) found that "the differences between video and real interactions are too large to consider that tests based on each kind of stimuli are evaluating the same construct" [74]. Sala and Gobet (2017) found negative evidence for "far transfer" - applying skills in contexts very different from training - from chess, music, and working memory training [56]. Psychological, affective, and ergonomic fidelity, not visual fidelity, appear to be the primary determinants of successful transfer.

Cognitive overload in complex simulations can paradoxically impair learning. Fraser et al. (2012) found that **25–30% of medical students failed to recognize a cardiac murmur** they had been trained on just one hour earlier when cognitive load exceeded optimal thresholds [53]. Haji et al. (2016) demonstrated that reduced task complexity produced superior performance and lower cognitive load during both acquisition and retention phases

[54]. The evidence points to an optimal cognitive load zone of **3–6 on a 9-point scale**, with scores above 7 associated with declined performance. Progressive complexity scaffolding - starting simple and gradually increasing challenge - is essential.

The uncanny valley effect operates subconsciously. Howard (2017) found that simulations with mismatched realism levels (e.g., high-fidelity environment with low-fidelity controls) produced the worst learning outcomes, while consistently low or high realism produced the best [55]. Participants did not report differences in engagement, yet their performance scores diverged significantly - suggesting the effect "encumbers cognitive resources" without awareness. Chaturvedi et al. found that cartoon-style characters had greater emotional impact than realistic avatars in nursing VR [57], supporting the use of stylized rather than photorealistic designs.

Practicing incorrect behaviors without feedback is a serious risk. INACSL Standards explicitly state that "learning without guidance could lead the learner to negatively transfer a mistake into their practice without realizing it had been poor practice" [58]. Ericsson's deliberate practice framework requires real-time, constructive feedback [61][62] - without it, practice does not lead to improvement but merely reinforces existing patterns. Debriefing is considered the single most important component of simulation-based learning, and AI-powered simulations must incorporate structured, accurate feedback mechanisms to be effective.

Additional limitations include **cybersickness** (up to 57% incidence in some VR studies), the **novelty effect** wearing off over time (Merchant et al., 2014 found learning may decrease as VR session count increases) [59], **cost barriers** (VR requires 48% greater upfront investment, though parity is reached at 375 learners), and **individual differences** in simulation responsiveness based on age, prior technology experience, personality, and coping style. These limitations are generally mitigable through thoughtful design - but they are not trivial.

8. The evidence-based verdict on simulation and long-term skill retention

The convergent evidence from cognitive science, neuroscience, and training research supports a strong conclusion: **continued simulation practice is one of the most effective available countermeasures to the forgetting curve for interpersonal skills**, operating through at least four distinct mechanisms.

First, simulations **change the type of memory formed**. By requiring active performance rather than passive reception, simulation practice triggers Anderson's knowledge compilation process [1][2], converting fragile declarative knowledge into durable procedural memory that follows a fundamentally flatter decay curve. Second, simulations **strengthen initial encoding** through emotional arousal (amygdala-mediated consolidation) [9][10], desirable difficulties (deeper processing) [3], embodied cognition (motor-social integration) [34], and multi-channel encoding (episodic + procedural + emotional traces) [8]. Third, **spaced simulation practice directly counteracts skill decay** - the meta-analytic evidence showing g = 1.01 for spaced versus massed practice is unambiguous [72], and LDHF implementations have demonstrated maintenance of competency over 6–12+ months with brief, regular sessions [26][27]. Fourth, simulations create **transferable episodic templates** that serve as mental models for future real-world social problem-solving.

The quantitative picture is clear. Without any refresher practice, half of accuracy-based skill gains are lost by approximately 6.5 months [28]. With spaced simulation boosters at 2–3 month intervals, skills can be maintained at or near mastery levels for 12+ months [47][48]. Leadership training meta-analyses show that spaced, practice-based approaches produce **28% increases in on-the-job behavioral change** [32] - not just knowledge, but actual leadership behavior. The SIMmersion employment outcomes (56% vs. 27%) [44] and Laerdal survival rate improvements (21% increase) [33] demonstrate that simulation-trained skills translate to real-world results.

For an AI-powered leadership simulation platform, the evidence supports several design principles:

- **Distribute practice over time** rather than concentrating it in single sessions; optimal intervals appear to be every 2–3 months for maintenance, with brief booster sessions between [15][24][47]
- **Ensure structured feedback/debriefing** after every simulation - this is non-negotiable for effective learning and preventing negative practice effects [58][61]
- **Design for moderate emotional engagement** - scenarios should generate enough interpersonal challenge to activate the amygdala-hippocampus consolidation pathway without inducing cognitive overload [9][10][53]
- **Maintain consistent realism levels** across simulation elements to avoid uncanny valley effects; stylized avatars may outperform photorealistic ones that fall short [55][57]
- **Scaffold complexity progressively**, starting with lower-complexity scenarios and increasing challenge as competency develops [54]
- **Complement simulation with real-world practice opportunities**, as transferability improves when simulation-trained skills are quickly applied in authentic contexts [56]

The remaining gaps in the literature are significant but not disqualifying. Most longitudinal retention studies focus on technical rather than interpersonal skills. Independent peer-reviewed research on commercial platforms (Mursion, Strivr, Virti) is limited relative to vendor-reported data. The optimal spacing interval for interpersonal skill maintenance has not been definitively established. And the question of how well AI-generated social dynamics transfer to genuinely unpredictable human interactions remains under-studied.

Despite these gaps, the weight of evidence - from cognitive architecture theory, neuroscience of memory consolidation, meta-analyses of hundreds of studies, and emerging longitudinal data - converges on a clear conclusion. **Simulations do not merely slow the forgetting curve; they fundamentally alter the encoding pathway for interpersonal skills, creating more durable memory representations that, when maintained through spaced practice, persist far longer than knowledge acquired through traditional training methods.** The effect is not subtle - effect sizes of d = 0.71–1.20 represent some of the largest in educational intervention research [14][16]. Continued simulator practice is not just helpful for long-term skill retention; it may be the closest available approximation to the real-world repetitive practice that expertise research has long identified as the foundation of durable skill mastery [61][62][63].

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9. Why interpersonal skills can never become fully "permanent" - and what this means for practice design

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A natural follow-up question emerges from the preceding evidence: at what point does a skill become sufficiently proceduralized that simulation practice is no longer necessary? The research provides a clear answer, and it is one that has significant implications for how leadership development programs should be structured.

The open vs. closed skill distinction

Motor learning research classifies skills along a continuum from "closed" to "open" [65][66][68]. **Closed skills** are performed in stable, predictable environments - typing, riding a bicycle, performing a gymnastics routine, assembling a weapon. The environment does not change, and the motor sequence is essentially identical every time. **Open skills** are performed in dynamic, unpredictable environments requiring continuous adaptation - returning a tennis serve, defending in team sports, navigating a difficult interpersonal interaction. The performer must constantly read external cues and modify their response in real time.

This distinction is critical because **closed skills can reach near-permanence through overlearning, while open skills fundamentally cannot.** The "you never forget how to ride a bike" phenomenon is neurologically real - but it applies only to closed skills where a fixed motor sequence is stored in the basal ganglia and can be executed without hippocampal involvement or prefrontal decision-making. Procedural memory for a stable, repeating sequence is among the most durable forms of human memory, persisting even in patients with severe hippocampal amnesia [4].

Interpersonal skills - communication, persuasion, conflict resolution, decision-making under pressure - are fundamentally **open skills**. Every difficult conversation involves a different person, different emotional context, different stakes, different power dynamics, and different cultural considerations. There is no single motor sequence to automate. Effective interpersonal performance requires continuous integration of perception (reading the other person's emotional state, body language, and intentions), decision-making (choosing the right approach from a repertoire of strategies), and adaptive execution (adjusting in real time as the interaction unfolds). This means the prefrontal cortex and social cognition networks remain actively engaged even in highly practiced performers - the skill never fully "drops" into subcortical automaticity the way closed motor skills do.

Three research findings that rule out permanence

1. Ericsson: Experts decay when they stop practicing

In his 2004 paper in *Academic Medicine* and 2008 paper in *Academic Emergency Medicine*, K. Anders Ericsson documented that professionals who terminate deliberate practice experience what he termed "premature automation" - their performance plateaus at an acceptable but suboptimal level and then slowly degrades over time [61][62]. The best violinists in his landmark studies practiced approximately four hours daily even at peak career stages [63] — though the magnitude of deliberate practice's contribution to expertise has been debated [71]. Expert performers do not "graduate" from practice; they shift from skill-building to skill-maintenance, but the practice itself never ceases.

Critically, Ericsson found that observed performance in many professional domains does not correlate with greater experience - suggesting that years of experience without continued deliberate practice does not maintain, let alone improve, skill levels [61]. As one researcher summarized: "Ceasing to deliberately practice causes the performance plateau. People stop learning better techniques. Their performance slowly worsens over time as their autopilot skills atrophy."

2. Overlearning effects are short-lived for cognitive and adaptive tasks

A 1992 meta-analysis of 15 overlearning studies found that while extra practice beyond mastery does improve retention, the effects differ dramatically by task type [67]:

- For **physical (closed) tasks**, participants who overlearned actually *improved* during the retention interval - consistent with consolidation and automaticity of fixed motor sequences.
- For **cognitive tasks**, overlearned participants still showed progressive decay, and the overlearning advantage eventually disappeared entirely.

One study examining geography facts and word definitions found that overlearners recalled more at one week, but this advantage "gradually disappeared after the study" [69], leading researchers to conclude that overlearning may be inefficient for long-term retention of cognitive material. Since interpersonal skills are cognitive, adaptive, and contextual rather than fixed motor sequences, the overlearning-to-permanence pathway does not apply.

In contrast, for procedural motor tasks (like military weapon assembly - an M60), extended practice beyond mastery created strong retention [67]. The overlearning group demonstrated better performance after 8 weeks of not touching the weapon than the refresher group did after 4 weeks. But this was a closed, fixed-sequence motor skill - not an adaptive interpersonal one.

3. Overlearning creates rigidity - the opposite of what open skills need

A ScienceDirect synthesis of overlearning research notes that "the primary limitation of overlearning is the development of rigid mental scripts and learned motor behavior that lack adaptability and flexibility" [75]. For closed skills, rigidity *is* the goal - you want the bicycle-riding sequence to execute identically every time. For interpersonal skills, rigidity is a *failure mode*. A leader who responds to every conflict with the same memorized script, or who applies the same negotiation tactic regardless of the counterparty's motivations, is not demonstrating mastery - they are demonstrating premature automation. What maintains adaptive flexibility is continued exposure to *varied* practice scenarios that challenge the performer to read new situations and select appropriate responses.

The retention floor hierarchy

When modelling long-term retention across different training approaches, the research supports a clear ordering of residual retention "floors" - the minimum skill level that persists even after long periods without formal reinforcement. Each successive investment in deeper, more practice-intensive learning should produce a higher floor:

E-learning only (\~10%): Passive consumption of videos, modules, and quizzes produces primarily declarative knowledge with minimal procedural encoding [5]. Without any experiential component, retention is the lowest of all leadership development formats. This is the appropriate baseline for comparison - not the Ebbinghaus nonsense-syllable forgetting curve, which measures memorization of meaningless material and is not comparable to any form of leadership development.

Single workshop (\~15%): A 2-day intensive workshop creates some experiential memory through exercises and role-plays, plus episodic memories of the event itself. The experiential component decays more slowly than pure declarative knowledge, producing a moderately higher floor.

Multi-workshop program (\~25%): Three or more workshops spaced over several months benefit from the spacing effect [32] (Lacerenza et al., $\delta = 0.88$ for spaced vs. $\delta = 0.71$ for massed), Ebbinghaus relearning savings [5], and multiple opportunities for real-world application between sessions. Each subsequent workshop builds on a partially-retained base rather than starting from zero. This produces a meaningfully higher floor than a single event.

Workshops + simulation practice, even if practice stops (\~32%): Six months of regular simulation practice on top of workshops creates substantially more procedural encoding than workshops alone. The person has practiced skills dozens of times in varied scenarios, building a procedural memory base that - while it will erode faster than closed-skill procedural memory due to the open-skill nature of interpersonal work - still persists well above the workshop-only floor.

Workshops + ongoing simulation practice (70–95%+): With continued practice at maintenance frequency (monthly to quarterly), retention remains high [26][27][32]. The procedural base continues to build slowly, and each practice session both reinforces existing patterns and introduces variability that prevents rigidity.

This hierarchy is logically necessary: each additional investment in practice depth should produce a higher long-term floor. If a model shows a more intensive training approach producing the same or lower long-term retention than a less intensive one, the model's parameters need correction - that outcome contradicts both the research evidence and common sense.

The phased practice model

The evidence does not support a binary choice between "practice forever at the same intensity" and "graduate and stop practicing." Instead, it supports a **phased approach** in which the purpose and frequency of practice shifts over time:

Phase 1 - Intensive skill building (months 0–6): High-frequency simulation practice (weekly to biweekly) alongside workshops. The goal is initial procedural encoding - converting declarative knowledge about effective communication, conflict resolution, etc. into automated response patterns. This is the phase where the steepest learning gains occur and where the forgetting curve is most actively being counteracted.

Phase 2 - Consolidation and growth (months 7–12): Reduced frequency (monthly). By this point, a substantial procedural base has been established. Practice sessions shift from building new skills to deepening existing ones - more complex scenarios, more nuanced interpersonal dynamics, practicing skills under higher cognitive load or emotional pressure.

Phase 3 - Maintenance (month 13+): Further reduced frequency (bi-monthly to quarterly), continuing indefinitely. The goal is preventing the slow erosion of adaptive flexibility that Ericsson documented when deliberate practice ceases [61][62]. Sessions at this stage serve dual purposes: maintaining existing skills against decay, and exposing practitioners to novel scenarios that prevent the rigidity associated with overlearning.

Sullivan et al.'s (2019) four-tier simulation maintenance framework aligns with this model [52], distinguishing between initial training, maintenance (proactive, before skills decay), booster (reactive, when proficiency begins to wane), and refresher (re-establishing lost skills). The evidence consistently shows that proactive maintenance is far more efficient than reactive refresher training - it requires less time, produces better outcomes, and prevents the confidence loss associated with realizing one's skills have significantly degraded.

A note on model transparency and what the numbers can and cannot claim

The accompanying 24-month visualization models retention curves for each training approach using parameters drawn from two sources:

- **Research-anchored parameters** (tagged RESEARCH in the model): Values taken directly from meta-analyses or peer-reviewed studies - such as the procedural skill decay rate of \~0.08 SD/month from Tatel & Ackerman's 2025 meta-analysis [28].
- **Estimated parameters** (tagged ESTIMATED in the model): Values interpolated from best available evidence but not directly measured in any single study for the specific context of leadership interpersonal skills training. These include decay rates for e-learning vs. workshops, experiential-to-declarative ratios, simulation boost magnitudes, procedural conversion rates, and residual floors.

All estimated parameters are user-configurable via sliders so that assumptions can be tested transparently. The model should be understood as a **research-grounded thinking tool** - useful for illustrating the relative dynamics between training approaches and for exploring how different assumptions affect outcomes - not as a precision instrument producing exact predictions.

The strongest way to make the business case is to cite independent ROI and behavioral transfer evidence directly. The MIT Sloan/Shahi Exports RCT found soft skills training produced 256% ROI within 8 months [51], and Lacerenza et al. showed spaced, practice-based leadership training produces 28% more on-the-job behavioral transfer [32]. These figures carry weight precisely because they measure real-world outcomes — productivity gains, revenue impact, observable leadership behavior — rather than being derived from a retention curve model. What the retention model tracks is the behavioral change and performance improvement the training was meant to produce; the business impact studies then provide independent evidence of what that behavioral change is worth. Training budgets themselves (facilitator time, venue, travel, materials, participant time, program design) are sunk costs regardless of retention, so the compelling story is about protecting and extending the value those

investments were designed to create.

The "fitness" analogy: not a limitation but a positioning advantage

The practical implication for an AI-powered leadership simulation platform is significant: the value proposition is not "we'll train you until you're done" but rather **"we'll build your skills intensively, then maintain them efficiently - because the research shows that interpersonal expertise, like physical fitness, requires ongoing practice to sustain."**

This is not a limitation to be apologized for; it is the empirically grounded reality of how human skill acquisition works for complex, adaptive, open-skill domains [61][62][65][66]. The frequency decreases, the purpose shifts, but the practice itself should never fully stop. Just as no one expects a single gym membership to produce permanent physical fitness, no one should expect a single training program to produce permanent interpersonal skill mastery.

The 24-month visualization demonstrates this clearly: the purple "practice stops" curve shows skills settling to a floor that, while higher than workshops alone (reflecting the accumulated procedural encoding), is substantially below what maintenance practice sustains. The cyan "maintenance mode" curve shows that even infrequent quarterly practice preserves the vast majority of gains from the intensive phase - at a fraction of the ongoing time investment. The gap between these two curves at month 24 represents the cost of assuming skills are "permanent" versus the value of modest ongoing investment in practice.

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Note: Some industry reports and vendor case studies (PwC [40], Strivr [45], Bodyswaps [46], KPMG/HBS [50]) are referenced as evidence but are not independent peer-reviewed research. This distinction is noted in the main report where these sources are discussed.

Remaining editorial note

Section 1, forgetting curve percentages ("50% within one hour, 70% within 24 hours, 90% within a week"): Mapped to Ebbinghaus [5] and Murre & Dros [6]. These specific percentages are widely cited but are conventionalized approximations of Ebbinghaus's original data rather than exact figures from any single source. The mapping to [5] and [6] is the best available attribution.