Assessing Blue-Collar Workers Cognitive Skills Through Gamified Tasks and Analytics

Vanya Gupta
Student, Fravashi International Academy India
Email: vanya280908@gmail.com

Hitendra Vaishnav
Mentor, On My Own Technology Pvt. Ltd.
India
Email: hitendra.vaishnav@omotec.in

***Abstract*—This study presents a gamified framework for assessing the cognitive abilities of blue-collar workers in the manufacturing sector. Conventional cognitive testing methods, such as the Montreal Cognitive Assessment (MoCA), fail to capture the dynamic and high-pressure decision- making skills required for operating complex machinery. To address this gap, six Python-based mini-games were developed using Pygame to evaluate attention, memory, spatial reasoning, problem solving, and decision-making. A cohort of 20 industrial workers was assessed, and the total gamified scores demonstrated a strong positive correlation with MoCA results ($r = 0.74$, $R^2 = 0.682$). Furthermore, cognitive retraining and job-role reassignment of a welding operator showed significant improvements in both cognitive performance and operational efficiency. These findings establish the novelty and significance of gamified cognitive assessment as a scalable, engaging, and cost-effective approach to workforce optimization. The research outcomes contribute to industrial safety, productivity enhancement, and informed workforce deployment strategies.**

***Keywords*—** *Gamification, Cognitive ability, Workforce optimization, Python-based games, MoCA correlation*

I Introduction

The emergence of Industry 4.0 has transformed the nature of blue-collar work, shifting it from routine manual labor to tasks that require advanced cognitive abilities such as decision-making under pressure, vi- suospatial reasoning, sustained attention, and problem- solving. Machine operators and industrial workers are now expected to adapt quickly to dynamic environments while ensuring safety, precision, and productivity. These evolving requirements have highlighted the limitations of conventional cognitive assessments, such as the Montreal Cognitive Assessment (MoCA), which provide static, context-independent measures that often fail to capture the real-time cognitive challenges faced in industrial settings.

II Motivation

The primary motivation for this work lies in addressing the gap between traditional cognitive testing and the real-world demands of industrial environments. Standard assessments are time-intensive, disengaging, and insufficient for measuring domain-specific skills that directly influence machine operation and workplace efficiency. Furthermore, they lack scalability, making it difficult for industries to continuously monitor workforce cognitive performance. Gamification offers a promising alternative, as it combines interactivity, engagement, and simulation of operational conditions while maintaining the rigor of systematic assessment. A gamified frame- work thus has the potential to provide both workers and organizations with actionable insights, enabling smarter workforce deployment and retraining strategies.

III Objectives

To design six gamified mini-assessments, each mapped to critical cognitive domains relevant to indus- trial tasks.

To validate the effectiveness of these gamified tasks against an established baseline assessment, the MoCA test.

To demonstrate the real-world applicability of the framework through a case study on workforce retraining and role optimization.

IV Contributions

The main contributions of this research are as follows: **Framework Development:** A domain-mapped, gam- ified cognitive assessment system built using Python (Pygame), designed to replicate real-world cognitive demands in an engaging and scalable format.

Validation: Empirical evidence showing a strong cor- relation between gamified scores and MoCA results, confirming reliability and construct validity.

Practical Application: A case study demonstrating measurable improvements in cognitive performance and operational efficiency when gamified assessment is ap- plied to workforce optimization.

This structured approach not only addresses the gaps in conventional cognitive testing but also introduces a scalable and engaging system that can support workforce training, safety assurance, and productivity enhancement in industrial settings.

Literature Review

The study conducted by Joseph J. Thompson et al.[7] It is about the dynamics of expertise development; it brought to light a major flaw in past studies that were viewed as contrasting experts with novices. The method included collecting telemetry data from video games and analyzing the cognitive-motor, attentional, and per- ceptual processing of 3,360 Real-Time Strategy players across seven levels of expertise. The conclusion drawn was that the assumption of static variable importance in expertise development was wrong; rather, the predictive significance of identified variables changed from less to more as the competence level of the players increased. Limitations include ascertainable biases in the gaming sample and the difficulty in generalizing findings beyond the study context.

In the study by Sonia Valladares-Rodriguez et al.[8], Episodic memory was used as an assessment of cog- nitive impairment in elderly persons, quite limited in its usefulness for evaluating cognitive function by the traditional means of personal interviews and pen-and-paper methods. The new study proposes a digital game based on the gamification of the California Verbal Learning Test (CVLT), with respect to psychometric standards of reliability and validity. Earlier validation was conducted through two qualitative focus groups and an initial pilot study that yielded the conclusion that the digital game was ecological and less intrusive than traditional assessments and significantly shorter in administration time. The results are promising in terms of psychometric validity and usability and point toward the possible ability of the game to categorize cognitive status and predict mild cognitive impairment in older adults. Limitations were cited with some subsequent recommendations for research to further improve the resolution of the game for specific cognitive impairments and attempt to fully validate its psychometric properties.

Research conducted by Hyunjoo Song et al.[9] investigated cognitive control through a mobile game called ”CoCon,” designed with elements of gamification, and contrasted results with traditional neuropsychological tests. A sample of 100 participants ages 9-16 was used to explore relationships between CoCon game behavior scores and standardized tests, including K-WISC-IV, CTT, and Stroop. Results suggest that the mobile game assessment is a valid and reliable measure of cognitive control in children and adolescents, correlating significantly with a range of cognitive control functions and differentiating between high and low cognitive control groups. Although participants played the game in their own environments, CoCon scores were comparable to those from standard neuropsychological tests. Limitations included a need for further validation on different populations and settings to enhance generalizability.

The traditional cognitive ability assessments Faizan Ahmad et al.[10] studied have been considered inadequate for several reasons: they are expensive, lengthy, and sometimes intrusive. The authors proposed the non- invasive game analytic technique LAS to assess three cognitive abilities: Visual Long-term Memory (VLTM); Analytical Capability (AC) and Visual Short-term Mem- ory in Change Detection Paradigm (VSTMiCDP). In a cross-generational cognitive evaluation with an experi- mental group designed as a game, it was demonstrated that LAS could discriminate the targeted cognitive abil- ities on 5-point evaluation scales, with high correlations to results produced from traditional cognitive testing. These results strongly support the view that LAS now holds promise for a reliable and even enjoyable alterna- tive cognitive ability assessment that affords considerable comparability with traditional measures, albeit with a greater degree of participant enjoyment. The drawbacks point to the need for more robust testing with varying population demographics for better generalizability and the possibility of variability in engagement with the game influencing results.

Justin W. Bonny et al.[11] assessed a novel approach to the investigation of the interplay between gaming skill and cognition, thereby overcoming some of the limitations encountered by traditional methods of as- sessment. Participants were recruited from a Multiplayer Online Battle Arena (MOBA) gaming tournament and undertook a battery of cognitive tasks designed to mea- sure spatial working memory, long-term memory, simple cognitive processing, and gaming experience. Equality of reliability on the working memory task was shown in the results, and findings duplicated previous research on the same kind of task, thus establishing the validity and reliability of the data collected. The study found a significant correlation between gaming experience and response time for the location memory task, indicating that a greater level of gaming experience could improve recalling spatial information speedily. Performance may have been altered by conditions in the tournament, and it remains for research on the present findings to be extended to across genres and populations.

Tobias et al.[12] addressed aspects regarding cognitive loadful interface design by elaborating on the difficulty of assessing cognitive load. An eye-tracking framework was thus proposed for overcoming such limitations. This involves training classifiers for the prediction of cognitive load during a typical working memory task (n-back) and applying these classifiers to an emergency simulation game. Prior techniques were criticized for being subjective and task-specific, and thus generalized poorly, because of various technical limitations and dependence on performance data. The classifiers offered reasonable prediction efficiency across tasks and individ-

uals, with accuracies ranging from 63.78% to 67.25% in differentiating between hard and easy game levels. This therefore suggests that the presented eye-tracking method holds great promise for generalizing cognitive load assessment across tasks and subjects, enabling the design of novel computer-human interaction systems in gaming and educational settings. Among the drawbacks were that classifiers still require validation in a broader sweep of conditions and tasks to bolster robustness.

A new eye-hand coordination assessment method was conceived in the work of Milind Shah et al.[13]. In this research, they created a computer application using Python that sought to overcome the deficiencies of tra- ditional assessment methods that are usually costly and time-consuming. It uses the Pygame module to provide an attractive graphical user interface (GUI) that models visuo-motor interaction involving eye-shaped dot objects moving in a background image. This design also in- corporated pseudo-randomized coordinates generated by Random library, increasing the unpredictability of object placement with dynamically changing objects, thereby adding complexity to the assessment. The elapsed time during user interaction was recorded precisely by the Time module; thus, it is a systematic suspicious tool for precise assessment under an evaluation window size of 1200×600 pixels. The results showed a positive correla- tion between quicker response times and higher accuracy levels, shedding light on the trade-off between speed and precision in eye-hand coordination. Feedback and further analysis of the findings were presented by immediate console reporting. Some limitations required validation in larger populations and more diverse contexts for improved generalization and reliability.

Tiffany Tong et al.[14] presented the potential of serious games as screening tools for abnormal cognitive status, especially where traditional testing would not be feasible or costly, for instance, in emergency depart- ments. A feasibility study of 146 elderly adults was taken as the clinical sample in a game-based cognitive assessment on tablet technology. The performance data of the serious game were correlated with standard tools of mental status, which include the Mini-Mental State Examination (MMSE), the Montreal Cognitive Assess- ment (MoCA), and the Confusion Assessment Method (CAM). The results revealed that, after modifications, the game was successfully used across a wide range of elderly patients, with very high participation at 96.6%. Strong correlations were found between the game's per- formance and the MoCA (r=–.339, P ¡.001) and MMSE (r=–.558, P ¡.001) and with CAM (r=.565, P ¡.001), sug-
gesting the game adequately reflected cognitive status. Limitations of the study included further validation of the reliability of the game and its applicability in various clinical populations.

Pauline L. Baniqued et al.[15] studied the effective- ness of a video game-based mobile program, Mind Frontiers, on improving fluid intelligence and correcting some limitations of previous studies on finding mixed results concerning far transfer effects. Ninety participants underwent 20 sessions of training over a period of 4- 5 weeks, with 45 subjects assigned to Mind Frontiers and 45 to an active control group performing visual search and change detection tasks. Findings showed that there were improvements in the Mind Frontiers group on working memory n-back tests, perceptual speed, and reaction time on reasoning tests. No significant training- related improvements were found in reasoning accu- racy or any other cognitive domains, including episodic memory and attention. Limitations included a lack of improvement in some cognitive areas, signaling the need for more research to ascertain the broad applicability of Mind Frontiers as a cognitive training tool.

The research by Xiangyi Cheng et al.[16] and col- leagues sought to resolve the issues posed by traditional cognitive assessments based on physical objects, which are too often expensive to set up and laborious in administration, and difficult to keep error-free by man- ual recording. The present study describes the e-Cube, a computerized vision-based cognitive assessment tool whose main objectives were to automate administration and scoring while minimizing the costs and time for the whole assessment procedure. The protocol comprised six games of the e-Cube administered to assess different cognitive domains and used an N80 participants com- parison in fixed and adaptive groups. Results indicate that measures of play complexity correlated highly with measures of performance, with significant correlations emerging for the adaptive e-Cube games against the WAIS-IV subtests. The e-Cube system had a low false detection rate and a high usability score, indicating good technical reliability. Some limitations are, nonetheless, that validation studies need to be undertaken to better substantiate the e-Cube's utility in the different popula- tions and settings.

The study by Franziska Leutner et al.[17] explored gamification and machine learning in the recruitment context, focusing on the problem of traditional cognitive assessments, which are often tedious and unfair to users. They validated a game-based assessment of cognitive ability using a machine-learning scoring algorithm that was optimized with regard to validity and fairness us- ing data from 11,574 assessment completions. Results indicated convergent validity (r = 0.5) and test-retest reliability (r = 0.68), suggesting that it assesses cognitive ability quite well. The Net Promoter Score indicated that, of 4,778 job applicants, this assessment format was perceived positively, though there were issues raised about its face validity. Other limitations include a rec-

ommendation for further exploration of the relationship between anxiety, gender, and performance.

According to research conducted by Stuart Hagler et al.[18], The early and reliable identification of cognitive decline poses a critical challenge in the study and aims to harness a computer game frequently played by laypeople to tap into various cognitive processes and estimate paper-and-pencil Trail Making Test (TMT) results. The model works by decomposing TMT into independent processes, each of which is described by parameters estimated from gameplay. An empirical evaluation of this model suggested that game data could be used to provide valid estimates of the parameters of the underlying cognitive processes, which serve to predict the performance on the TMT. Results further indicated that cognitive measures derived from gameplay could identify individuals requiring further assessment, thus promoting the early detection of neurological problems and providing ongoing feedback for cognitive rehabili- tation at home. Limitations included the need for further validation of the model across different populations and settings to ensure robustness and generalizability.

Holly B. Jimison et al.[19] proposed a method that would use enjoyable computer games embedded with cognitive metrics to measure within-subject trends. A set of nine computer games was developed to mea- sure various cognitive domains typically assessed in routine neuropsychological evaluations: verbal fluency, working memory, attention, and planning. While the assessments were not conducted in controlled environ- ments, the very possibility of frequent data collection in a naturalistic setting minimized biases associated with education, culture, and experience, thereby allowing for different advantages in tracking trends in cognitive performance. The findings suggest that these assessments are capable of detecting changes in performance over time. Limitation-wise, gameplay experiences may vary to some degree, and more validation would need to be done concerning the games' utility for different populations.

The study by Teun Aalbers et al.[20] essentially concerned itself with BAM-COG, or Brain Aging Monitor-Cognitive Assessment Battery, in terms of its alter- nate forms of reliability, face and content validity, and convergent and divergent validity. BAM-COG encompasses four puzzle games wherein participants engage in tasks harnessing working memory, visuospatial short- term memory, episodic recognition memory, and plan- ning. In total, 641 subjects were recruited: 397 adults 40+ were subjected to analysis. Results indicated that alternate forms' reliability was bound to be adequate for three of the four games, while good convergent validity with established tests of cognition was achieved. In par- ticular, the promising psychometric qualities lay with the games "Conveyor Belt," "Sunshine," and "Papyrinth"; these turned out to be less respectable than the game "Viewpoint." Some limitations included the necessity for applying further validation on a broader population to ensure further generalizability.

Yi-Shiuan Chou et al.[21] proceeded in the develop- ment of a mobile educational game, "Void Broken: The Qing Dynasty," to improve learners' cognitive thinking. A quasi-experimental design was employed with high school freshmen of 70 subjects from northern Taiwan, selected through convenience sampling. The study an- alyzed the historical knowledge gains from participants and flow states. An operational behaviour coding scheme was used to evaluate the learning behaviours and col- laborative problem-solving (CPS) during game-based learning. The result indicates that the cognitive operative mechanism of the game promotes historical knowledge acquisition, flow experience, and CPS behaviour among learners. Concerning flow, high flow groups exhibited more active, multidimensional problem-solving patterns than low flow groups. The limitations related to the small sample size and possible biases due to convenience sampling may pose challenges to such findings.

Methodology

The method of research in this context involves sev- eral stages that ensure the efficacy of cognitive ability assessment using a gamification strategy for employ- ees within the blue-collar sector of the economy. This covers the recognition of cognitive abilities that are needed to perform tasks in a specific sector, creation of specific and appropriate mini-games for assessing the cognitive abilities, continuous data collection and record-keeping for the research process, marking of the performance, etc, assisting in making recommendations for work enhancement. It also involves the translation of the evaluation of cognitive skills to function coding, as well as linking the results of the assessment to the actual performance measures. The design of very engaging educational evaluations is lacking, and it is the major justification for this approach for industrial-oriented skills training.

1. Conceptual Framework

The composite cogni

where s_i is the score
domain C_d. The corr

A . Cognitive Domain Mapping for Industrial Tasks

For a systematic evaluation of blue-collar workers' cognitive capacities, it is important first to identify the cognitive domains that are applicable to different

kinds of industrial tasks. In order to break down the job profile in terms of its fundamental cognitive requirements—sustained attention, quick decision-making, spatial reasoning, working memory, and motor coordination—this procedure would involve a thorough task analysis. For precision tasks such as the manipula- tion of machines, one needs to have good hand-eye coordination and fast reflexes, whereas logistics tasks are more demanding in terms of spatial visualization and problem-solving. This framework will facilitate the development of gamified assessments in which each mini-game will validly measure cognitive competencies. Therefore, matching assessment criteria with real-world job performance criteria will result in better placement of workers within the organizations, improved training programs, and minimized workplace risk due to the mismatch of cognitive skills.

B. Creating a game and correlating it with the cognitive domain

These six games have been developed using Pygame. Each of these games was aimed at assessing a different area of cognition or specific cognitive function related to industrial tasks. It also caters to sustained attention, decision speed, spatial reasoning, problem solving, working memory, and motor coordination. For example, tasks focusing on attention and concentration help gauge the capacity of an individual to attend to tasks without distraction, while games exploring decision making provide an idea of how quick and accurate responses would be in a constantly changing situation. On the other hand, spa- tial reasoning and visualization tasks serve to determine a person's ability to mentally manipulate objects — which is critical in logistics and assembly operations — as well as evaluations of analytical employability parameters through problem-solving and logical- reasoning chal- lenges, and real-time operational capabilities in stored and utilized knowledge through the working- memory condition. Finally, motor coordination and reflex-based games measure reaction time and precision, especially for machine operators who deal with heavy and very complex machines. Each game is constructed in such a way that it closely resembles real-life scenarios that an industrial worker would encounter while at work, thus giving credence to the cognitive skill evaluated in performance at the job site. Table 1 shows the six types of games created for cognitive ability and mapped to various machines. By screening the performance of players within these mini-games' folds, an understanding can be obtained of their suitability for particular job categories, their training needs, and the possible risks they would pose to the workplace, thereby improving effective employee deployment and operations at work- places.

Type of Machine	Game Type	Cognitive Domains to Map
Cutting Machine	Game 1: Rotating Blades	Attention
Press Machine	Game 2: Press machine game	Attention, decision making
	Game 3: Memory clock game	Memory
Conveyor System	Game 4: Save the Forklift	Visuospatial reasoning and attention
	Game 5: Tangram Puzzle	Visuospatial Reasoning
	Game 6: Machine repair game	Problem solving and memory

TABLE I: The types of machines and the cognitive ability required to operate the machines

C. Using Pygame to Develop Games and Define the Scoring Pattern

The Pygame-designed cognitive assessment games have been tailored for evaluating individual cognitive aptitudes against the background of work within an organization. For example, each game lasts for a period of 60 seconds during which players engage in task- oriented challenges. Rather than determining accuracy, scoring is done by assigning a score out of 10 based on how well each demonstration time taken within the 60 seconds has been recorded for analyzing response speed and engagement. Such a lucid evaluation tech- nique ensures a smooth assessment of cognitive talent while bringing strengths and areas for improvement into view in the organization. Game 1 (shown in Figure 1): Rotating Blades is based on attention-being able to stay focused to avoid dangers from moving objects and reacting fast. Game 2 (shown in Figure 2), Press Machine Game, measures a combination of attention and decision making by asking players to make a decision by pressing a button at the right moment, with time constraints. Game 3(shown in Figure 3) is the Memory Clock Game and is a game about memory because it requires players to memorize and repeat patterns or sequences, as in a retention scenario. Game 4(shown in Figure 4), Save the Forklift, has improved visuospatial reasoning and attention since players were able to nav- igate a forklift through obstacles. It was the one that bolstered spatial awareness and focus. Game 5(shown in Figure 5): Tangram Puzzle gives more emphasis to visuospatial reasoning as players need to manipulate the geometric shapes so they fit specific patterns, thereby using spatial visualization and problem-solving skills. Game 6(shown in Figure 6): Machine Repair Game-it requires identifying machine faults and repairing them. This is just like the actual troubleshooting task required for working in the machine maintenance industry. The analysis from these games will deliver in-depth and in- sightful information for workforce optimization and will help organizations in making wise decisions regarding training, job assignments, and safety.

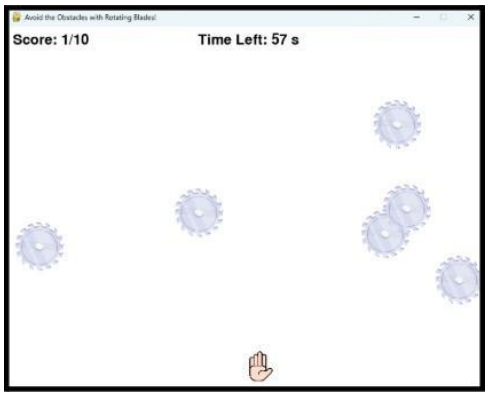

Fig. 1: Game 1: Rotating Blades

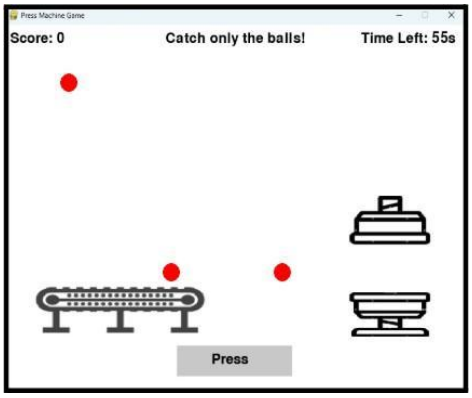

Fig. 2: Game 2: Press Machine Game

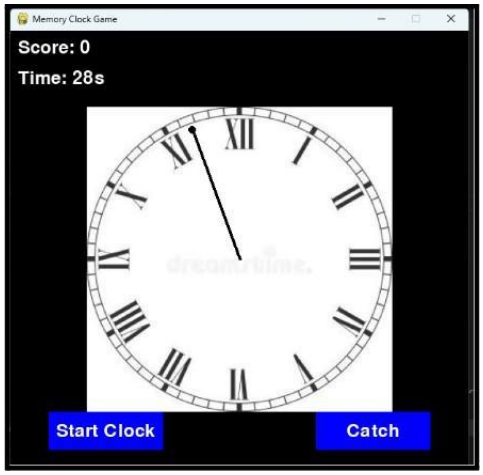

Fig. 3: Game 3: Memory Clock Game

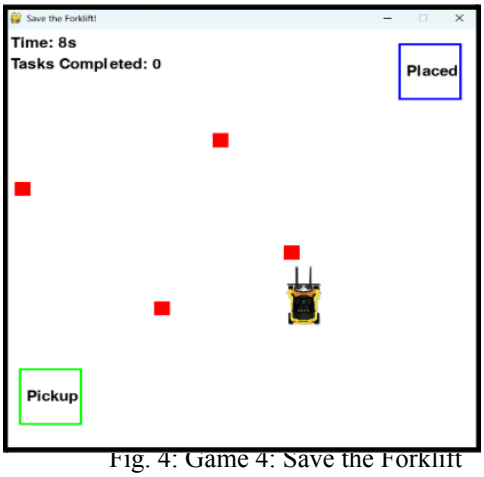

Fig. 4: Game 4: Save the Forklift

Fig. 5: Game 5: Tangram Puzzle

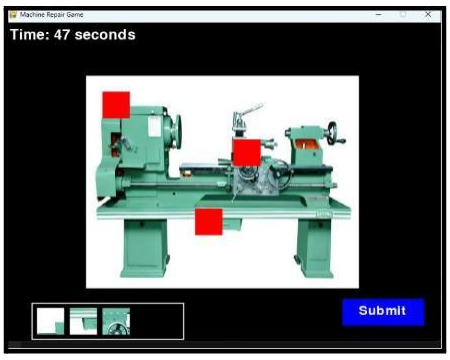

Fig. 6: Game 6: Machine Repair Game

D. Cognitive Assessment Validation Using MoCA and Gameplay Scores

To validate the effectiveness of the developed gam- ified cognitive assessments, we compared the game performance scoring of blue-collar workers with their MoCA (Montreal Cognitive Assessment) scores, which is a well-known benchmark assessment in practitioner

circles. The MoCA assesses cognitive domains including visuospatial skills and executive functioning, attention, memory, language, abstraction, orientation, which are roughly parallel to those measured in our six cognitive games. The mapping was achieved using a normalized scoring system. Each game score (out of 10) was aligned with a corresponding MoCA domain, shown in Table 2:

Game	Mapped Cognitive Domain	Corresponding MoCA Section
Rotating Blades	Attention	Attention
Press Machine Game	Decision-Making, Attention	Executive Function
Memory Clock	Memory	Delayed Recall
Save the Forklift	Visuospatial Reasoning	Visuospatial/Executive
Tangram Puzzle	Spatial Reasoning	Naming/Visuospatial
Machine Repair	Problem-Solving	Abstraction

TABLE II: Correlation between the game cognitive domain with the MoCA cognitive domain.

Further a composite cognitive game score was calculated for each participant and correlated it statistically with their MoCA score using Pearson's correlation and regression modeling to evaluate cognitive alignment.

E. Tracking of Job Role Performance and Automation Transition

After each game assessment and the MoCA test, participants were assigned to performance tiers. Employees exhibiting high cognitive scores but working on basic manual tasks (such as welding or pressing machines) were earmarked for advanced machine operation train- ing. Particularly:

One employee was trained on a robotic welding machine after he mastered the Memory Clock and Tangram Puzzle games. His quality output (weld consistency, cycle time, and defect rate) was monitored pre- and post-intervention.

V Results and Discussion

The analysis of the cognitive scores blue-collar workers obtained from six gamified tasks relevant to spe- cific industrial cognitive skills revealed interesting trends when considered together with their occupational pro- files, types of machines used, and their MoCA stan- dardized cognitive test scores. Each participant's score was calculated based on their performance in the six games, resulting in a maximum score of 60. Out of all 20 participants, the mean total cognitive game score was 38.25, with the highest result being 54 and the lowest 24, suggesting considerable variability in cognitive functioning within the worker group.

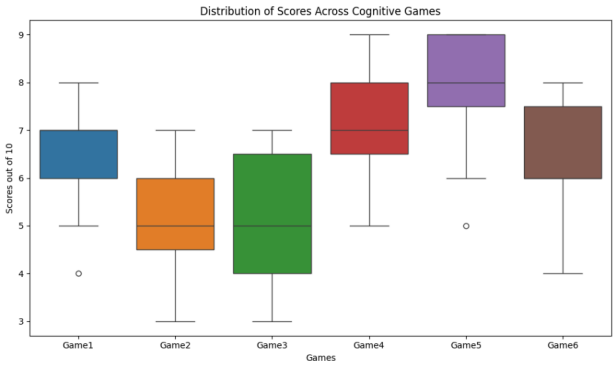

Fig. 7: Score distribution of all the workers across all cognitive games

In terms of specific games, the best performance was in Game 5 (Tangram Puzzle) which had an average score of 7.6 out of 10, indicating that spatial reasoning ability is a relative strength for this group. On the other end of the spectrum, Game 2 (Press Machine Game) had the lowest average score of 5.1, indicating difficulty with real-time decision-making under pressure. This is consistent with prior workplace observations where press machine handling operational errors were common before workers underwent cognitive training. The comparative boxplot presented in Figure 7 illustrates every worker's score for all games and shows that Games 4 and 5 scoring concerning spatial awareness and visuospatial coordination performed better than other games that is, their interquartile ranges were less than other games, demonstrating consistency across workers in these skills.

Fig. 8: Correlation between the game score and MoCA score

To assess the utility of gamified assessments, the MoCA score of each employee was plotted with their corresponding total game score. A Pearson correla-

tion coefficient of 0.74 was calculated, demonstrating a strong positive correlation. This confirms the hypoth- esis that high game scores and high MoCA cognitive performance are linked, providing at least preliminary validation that the games are appropriate for cognitive screening. Moreover, the scatterplot in Figure 8 illustrates this correlation as data points closely follow a rising trend line. The linear regression model provided an R^2 value of 0.682, meaning that roughly 68.2% of the variance in MoCA scores can be accounted for by game-based cognitive scores. Such high predictability justifies the use of gamified assessments for comprehensive and remote evaluation of cognitive skills.

An illustrative example is Worker ID 14, a welding machine operator. His first score on the gamified tests was 36 out of 60, with the biggest gaps being Memory Clock (Game 3, score = 4) and Machine Repair (Game 6, score = 5). After a positive selection and upskilling based on his performance in Visuospatial Games 4 and 5, and retraining on a robotic welding system, his game scores improved to 50 out of 60 post-training. In particular, his memory game score increased from 4 to 8 and his machine repair score from 5 to 8, showing cognitive flexibility with regard to skill-shaping training. This improvement is documented in Figure 9, a pre- and post-training line plot showing game scores for all six domains.

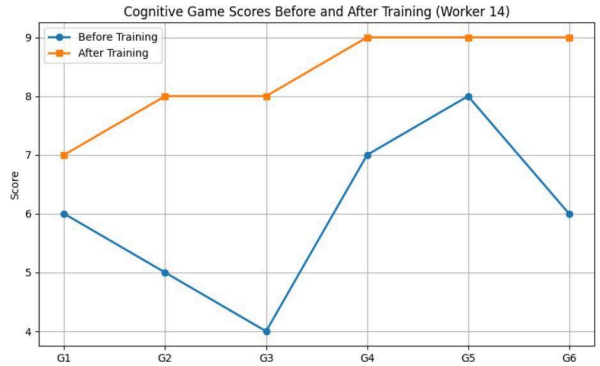

Fig. 9: Improvement in welder after training based on the cognitive score

The quality inspection records validated these find- ings. Following the training, his welding defects de- creased from 12% to 4%. Furthermore, his average cycle time improved from 45 seconds to 28 seconds per cycle, a notable enhancement in both efficiency and quality. This self-reported performance was also seen in the CSV data, where the worker rated his post-training confidence and comfort level as high compared to his prior moderate rating. As shown in Figure 10, you may observe one of the samples prepared by the welder during and after the training sessions. “A” shows the job position prior to training, whereas “B” reflects the job position after training. It seems, at least superficially, that the welder saves both material and time during the processes while also providing a greater quality of work.

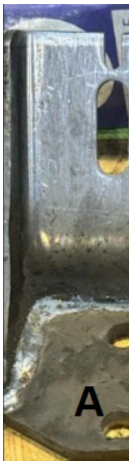

Fig. 10: Improvement in welding technique

Additionally, an analysis pertaining to job functions revealed that employees working on conveyor systems performed better on average (42.7) than those assigned to press machines (36.3). Perhaps this was due to the conveyor systems having lower mental workload require- ments or better overall organization. This underscores the importance of cognitive-job fitting, which seeks to improve productivity and reduce risk by matching workers with tasks that suit their skill sets.

The combination of the MoCA tests, gameplay scores, and job performance provides a triangulated validation structure that proves the effectiveness of gamification as a means to not only mirror cognitive capabilities but also as a tool to inform reskilling, worker assignments, and machinery modifications. The upward trend of post- training cognitive scores, along with improvements in quality metrics, affirms the methodology employed in this study and emphasizes the importance of cognitive assessment in transforming blue-collar workers.

VI Conclusion

This study demonstrates that gamified cognitive assessment offers a powerful alternative to traditional methods for evaluating blue-collar workers in industrial environments. By embedding six carefully designed Pygame-based mini-games into the assessment process, the framework successfully captured real-world cognitive requirements such as decision-making under pressure, spatial reasoning, and memory retention. The strong positive correlation with MoCA scores confirms its validity, while the case study of a welding operator

illustrates its practical utility in guiding workforce retraining and role reassignment. Despite these promising results, certain limitations exist. The study involved a relatively small sample size of 20 workers, limiting generalizability across industries. The scoring system, though effective, requires refinement with larger datasets to establish population-specific benchmarks. Additionally, while the games were designed for manufacturing contexts, cross-sector validation is necessary for broader adoption. Future work will focus on three directions: (i) integrating machine learning models to predict long-term job performance from cognitive game data, (ii) expanding the system to include multimodal inputs such as eye-tracking and biometric data for higher accuracy, and (iii) enhancing scalability through cloud-based platforms that enable remote cognitive monitoring at scale. By addressing these aspects, gamified assessment can evolve into a standard industry practice, promoting worker safety, operational efficiency, and human–machine synergy in the era of smart manufacturing.

References

[1] P. B. Lavenex, et al., "Well-designed Manufacturing Work Improves Some Cognitive Abilities in Individuals With Cognitive Impairments," *Frontiers in Rehabilitation Sciences*, vol. 5, May 2024. Available: https://doi.org/10.3389/fresc.2024.1377133.

[2] Sahi, "Mastering Manufacturing Excellence: The Role of Skill Assessments," Sahi, 28 Dec. 2023. Available: sahi.ai/mastering-manufacturing-excellence-the-role-of-skill-assessments.

[3] A. V. Carvalho, et al., "Cognitive manufacturing in industry 4.0 toward cognitive load reduction: A conceptual framework," *Applied System Innovation*, vol. 3, no. 4, p. 55, 2020.

[4] L. J. Elliott, et al., "Assessment of Metacognitive Skills in Design and Manufacturing," 2020 ASEE Virtual Annual Conference Content Access, 2020.

[5] N. Dadashi, et al., "Cognitive and metabolic workload assessment techniques: A review in automotive manufacturing context," *Human Factors and Ergonomics in Manufacturing & Service Industries*, vol. 32, no. 1, pp. 20–34, 2022.

[6] Advanced Technology Services, "Cognitive Computing in Manufacturing," Advanced Technology Services. Available: www.advancedtech.com/blog/cognitive-computing-technology-in-manufacturing.

[7] J. J. Thompson, et al., "Video game telemetry as a critical tool in the study of complex skill learning," *PLoS One*, vol. 8, no. 9, e75129, 2013.

[8] S. Valladares-Rodriguez, et al., "Design process and preliminary psychometric study of a video game to detect cognitive impairment in senior adults," *PeerJ*, vol. 5, e3508, 2017.

[9] H. Song, D.-J. Yi, and H.-J. Park, "Validation of a mobile game-based assessment of cognitive control among children and adolescents," *PLoS One*, vol. 15, no. 3, e0230498, 2020.

[10] F. Ahmad, et al., "A pilot study on the evaluation of cognitive abilities' cluster through game-based intelligent technique," *Multimedia Tools and Applications*, vol. 82, no. 26, pp. 41323–41341, 2023.

[11] J. W. Bonny, L. M. Castaneda, and T. Swanson, "Using an international gaming tournament to study individual differences in MOBA expertise and cognitive skills," Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, 2016.

[12] T. Appel, et al., "Cross-task and cross-participant classification of cognitive load in an emergency simulation game," *IEEE Transactions on Affective Computing*, 2021.

[13] M. Shah, et al., "Design and Implementation of a Python-Based GUI Tool for Eye-Hand Coordination Analysis," *International Conference on Inventive Communication and Computational Technologies*, Singapore: Springer Nature Singapore, 2024.

[14] T. Tong, et al., "A serious game for clinical assessment of cognitive status: validation study," *JMIR Serious Games*, vol. 4, no. 1, e5006, 2016.

[15] P. L. Baniqued, et al., "Working memory, reasoning, and task switching training: Transfer effects, limitations, and great expec- tations?," *PLoS One*, vol. 10, no. 11, e0142169, 2015.

[16] X. Cheng, et al., "Computerized Block Games for Automated Cognitive Assessment: Development and Evaluation Study," *JMIR Serious Games*, vol. 11, e40931, 2023.

[17] F. Leutner, et al., "Game based assessments of cognitive ability in recruitment: Validity, fairness and test-taking experience," *Frontiers in Psychology*, vol. 13, 942662, 2023.

[18] S. Hagler, H. B. Jimison, and M. Pavel, "Assessing executive function using a computer game: Computational modeling of cognitive processes," *IEEE Journal of Biomedical and Health Informatics*, vol. 18, no. 4, pp. 1442–1452, 2014.

[19] H. B. Jimison, et al., "A neural informatics approach to cognitive assessment and monitoring," 2007 3rd International IEEE/EMBS Conference on Neural Engineering, IEEE, 2007.

[20] T. Aalbers, et al., "Puzzling with online games (BAM-COG): reliability, validity, and feasibility of an online self-monitor for cognitive performance in aging adults," *Journal of Medical Internet Research*, vol. 15, no. 12, e2860, 2013.

[21] Y.-S. Chou, et al., "Designing cognitive-based game mechanisms for mobile educational games to promote cognitive thinking: an analysis of flow state and game-based learning behavioral patterns," *Interactive Learning Environments*, vol. 31, no. 5, pp. 3285–3302, 2023.