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Analysis of Motor Learning and Depth Perception through Tangram Gameplay: An HCI Perspective

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Abstract

This study investigates the Tangram puzzle game as a frame work for examining depth perception and motor learning within the field of Human-Computer Interaction (HCI). Tangram, a traditional puzzle made up of geometric shapes, provides an engaging and adaptable platform to explore how interactive tasks foster cognitive and motor development. The research focuses on three objectives: first, to assess depth perception by analyzing how players manipulate two-dimensional (2D) shapes to construct perceptual representations of three dimensional (3D) structures, thereby enhancing spatial cognition; second, to demonstrate the suitability of Tangram as a lightweight and flexible experimental tool for systematically measuring user interaction; and third, to examine motor learning processes through the repeated manipulation of puzzle pieces, offering insights into the refinement of fine motor skills and hand–eye coordination. By embedding Tangram gameplay into a structured experimental design, this work contributes to HCI scholarship by highlighting the value of puzzle-based interaction in understanding cognitive processes, informing interface design, and advancing interactive systems that support learning, rehabilitation, and skill development.

***Keywords**:* Depth perception, Motor learning, Hand–eye coordination, Cognitive development

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1. Introduction

From a Human-Computer Interaction (HCI) perspective, the analysis of motor learning and depth perception is reframed by focusing on how users interface with interactive systems and tangible tools to develop spatial abilities and movement proficiency.

Motor learning, within the HCI domain, refers to the iterative process by which users acquire and refine movement coordination through their engagement with interactive platforms, tools, or environments. This learning is shaped by feedback, user interface capabilities, and the multimodal sensory input HCI systems can provide. Critically, HCI draws attention not only to the development of physical skills but also to the underlying cognitive processes that are recruited during interaction, such as attention management, spatial reasoning, and strategic problem solving.

Depth perception, in HCI, is conceptualized as the ability of users to effectively interpret and operate within 3D or spatially complex digital and physical environments. Whether manipulating virtual objects, navigating a 3D interface, or solving spatial puzzles, the user's ability to make accurate spatial judgments is a core concern of usability.

The Tangram puzzle, as utilized in this study, serves as an experimental HCI platform uniquely suited to explore the integration of perception, cognition, and motor activity. The players interact with seven geometric pieces, rotating and positioning them on a physical or digital surface. This activity involves simultaneous visual feedback, spatial reasoning, and mirroring real-world HCI scenarios where users interact with tangible objects, touchscreens, or augmented reality systems.

By requiring users to construct target shapes from 2D elements, Tangram puzzles foster spatial thinking, adaptive problem solving, and the translation of cognitive plans into coordinated actions. The research aims to reveal how this tangible, feedback-rich interaction accelerates motor learning and sharpens depth perception, insights that contribute to the user-centered design of interactive technologies. From this point of view, Tangram is more than a playful activity since it is both a medium for experiential learning and a testbed to evaluate how design elements, feedback mechanisms, and task constraints support the development of spatial and motor competencies.

Under the umbrella of these facts, this research pursues three core objectives. First, it investigates how users engage with Tangram puzzles to understand and enhance depth perception, specifically by analyzing the ways participants manipulate 2D pieces to form perceptual models of 3D structures, thereby supporting spatial cognitive development. Second, the study demonstrates the value of Tangram as a lightweight and versatile experimental tool, capable of systematically capturing user interaction data and behavioral patterns within HCI research contexts. Third, it explores motor learning by examining how repeated manipulation of puzzle pieces drives the refinement of fine motor skills and hand–eye coordination over time.

By embedding Tangram gameplay within a structured experimental protocol, this research makes a distinct contribution to HCI by showcasing the unique potential of puzzle-based activities for probing the cognitive and perceptual dimensions of human interaction. The study findings inform best practices in interface design and provide evidence for the effective use of interactive and embodied tasks in the promotion of learning, rehabilitation, and acquisition of emerging skills within digital and physical environments.

The rest of the paper is structured as follows. Section 2 presents the related works. The problem statement and main content are discussed in Section 3. Section 4 introduces the results and discussions. The study's conclusions are presented in Section 5.

2. Related Works

To structure the review, we categorize prior research into three interrelated themes: studies focusing on depth perception, works addressing motor learning and hand-eye coordination, and investigations highlighting educational applications. This organization allows us to synthesize findings across different domains while directly linking them to our research objectives.

2.1. Depth Perception

In this subsection, we review prior studies that investigated the links between tangram gameplay, depth perception, and motor learning, highlighting how these interactive tasks contribute to visuospatial reasoning and cognitive development. Ayaz et al. [1] examined cortical activation during computerized tangram problem solving using Functional Near-Infrared Spectroscopy (fNIRS). Their findings revealed increased right prefrontal activation during tangram tasks compared to control conditions, with greater hemodynamic responses observed in unsuccessful trials. These results indicate that tangram puzzles demand significant executive planning and visuospatial reasoning, while also highlighting the utility of fNIRS as a portable tool for monitoring cognitive workload in educational contexts. This study provides a neurophysiological basis for linking tangram gameplay with cognitive development, aligning closely with our focus on depth perception and motor learning.

Li et al. [2] investigated the effects of stereoscopic 3D video game play on depth perception in young adults with normal vision. After forty hours of gameplay, participants showed a significant improvement in stereoacuity (i.e., the precision of depth judgments), while stereo bias (accuracy) remained unchanged. The findings suggest that immersive 3D environments enhance the precision of stereopsis without necessarily reducing depth bias, highlighting the potential of stereoscopic games as a training tool for binocular vision and fine visuomotor coordination. This study provides empirical evidence linking interactive gameplay to depth perception enhancement, which is directly relevant to our investigation of how structured puzzle tasks such as tangrams foster spatial awareness and cognitive development.

A significant study addresses the role of depth perception in motor skill development, highlighting how depth perception helps execute motor movements. The study highlights the importance of visual processing in guiding physical actions [3]. Another study examined depth perception in 3D video technology, introducing the concept of Just Noticeable Difference (JND) in depth perception. The study assessed how users perceive small differences in depth. Additionally, the study provides insights into how depth perception impacts visual experiences. Although this study focuses on 3D video technology, its findings are highly relevant to the game Tangram, in which players must evaluate spatial relationships and depth while arranging pieces in 2D to create 3D objects [4].

Recent research [5] titled “Measuring 3D Video Quality of Experience (QoE) Using a Hybrid Metric Based on Spatial Resolution and Depth Cues”, introduced a hybrid 3D-video QoE evaluation method that models the human visual system (HVS) through depth-related parameters such as motion information, blurriness, retinal-image size, and convergence. Their study demonstrated that subjective quality assessments, though accurate, are costly and time-consuming, highlighting the need for objective QoE metrics aligned with human depth perception. By integrating spatial resolution and depth cues, the proposed approach achieved a high correlation with subjective evaluations, suggesting that depth modeling is a key determinant in 3D visual realism. This work provides a strong foundation for understanding how the HVS processes depth information and offers a scalable framework for real-time QoE estimation, which can also inform educational and interactive 3D applications relying on spatial and perceptual feedback.

A recent study [6] explored how immersive 3D environments and depth cues influence perceptual accuracy and user performance in interactive tasks. The authors examined how atmospheric perspective and varying viewing angles within a 3D puzzle game affected users’ depth perception, motor control, and task completion time on an autostereoscopic display. Their findings showed that enhancing depth cues not only improved spatial awareness but also activated mirror neuron responses associated with motor learning. These results highlight the importance of realistic depth rendering and stereoscopic feedback in promoting perceptual engagement in 3D visual tasks.

Byunn-Rieder investigated the application of autostereograms in video games and demonstrated how to create depth illusions without specialized hardware. In addition, Byunn-Rieder addressed the potential clinical value of autostereogram- based games. Thus, he suggested that playing structured games could improve stereopsis and depth perception. [7].

Zerebecki conducted a series of experiments on stereoscopic 3D video games to investigate how different depth cues affect player immersion, performance, and learning. He observed that stereoscopic 3D can increase perceived immersion and provide more natural depth cues. However, he also emphasized that it can present challenges, such as increased control complexity and steep learning curves, for players unaccustomed to navigating along the depth axis [8].

Knill showed that the brain uses depth cues (binocular and monocular) differently. Motor control in tasks such as object placement relies more heavily on binocular cues, while perceptual judgments use both cues more evenly. This suggests that the brain integrates cues differently depending on the task, and that binocular vision is more important for precise movements [9].

Volcic and colleagues showed that visuomotor adaptation affects not only depth perception but also tactile sensitivity. After participants adapted to the hand-reaching movement with modified visual feedback, their depth perception adjusted to this new distance, and tactile sensitivity in their forearms increased. This suggests that depth perception is continuously adjusted with movement experience and body representation [10].

Hoffman compared depth perception in Virtual Reality (VR) with monocular and binocular displays. The results showed that the stereoscopic display increased both accuracy and engagement in interactive tasks, while the monoscopic display led to an underestimation of depth. This study demonstrates that display format influences depth perception and performance, and that binocular vision is important for learning [11].

2.2. Motor Learning and Hand-Eye Coordination

In this subsection, we review prior studies that investigated motor learning and hand-eye coordination in relation to stereoscopic depth and immersive virtual environments. These works collectively emphasize how visuomotor performance is shaped by depth cues and perceptual processing demands, while also providing insights into age-related differences and the unique characteristics of VR-based interactions.

Kim et al. [12] examined how stereoscopic 3D objects influence motor control during reaching tasks in virtual reality, with a particular focus on age-related differences. Fourteen young and 23 older adults made reaching movements towards both 2D and 3D targets at varying distances. The results showed that older adults exhibited significantly higher endpoint errors and reduced smoothness in the 3D long-distance condition, indicating difficulties in predictive motor control. In contrast, younger participants demonstrated sensitivity to stereoscopic signals only in long-distance tasks. These findings highlight that stereoscopic depth information increases cognitive and motor demands, with effects modulated by age-related changes in visuomotor integration. The study underscores the importance of considering stereoscopic depth in VR-based motor learning and rehabilitation contexts.

Juliano et al. [13] investigated how visual information for action is processed in Immersive VR (HMD-VR) when interacting with 3D objects. Using a Garner interference task, they found that grasping virtual 3D objects produced interference effects in reaction times, indicating that actions in VR rely on holistic rather than purely analytical processing. This suggests that motor actions in VR environments are more susceptible to perceptual influences compared to real-world interactions, which are typically guided by analytical processing. These findings highlight critical differences between virtual and real-world visuomotor control, raising important implications for the design of VR-based motor learning and rehabilitation systems.

Recent advances in computer vision–driven robotics have emphasized learning- based approaches for hand-eye coordination and motor control. Xiao et al. [14] proposed Masked Visual Pre-training (MVP), which leverages self-supervised representation learning from real-world images to improve motor control from pixels. Their results showed that pre-trained visual encoders can generalize across different robotic tasks and even approach oracle-level performance, highlighting the power of large-scale visual pre-training for visuomotor learning.

Jin et al. [15] introduced a method for robot eye-hand coordination by watch- ing human demonstrations, where a task function is learned directly from raw video sequences using inverse reinforcement learning. The learned reward model is then integrated into an uncalibrated visual servoing controller, enabling generalization to changes in targets, illumination, and occlusion while reducing hardware wear-out.

Huang et al. [16] developed Eye-on-Hand Reinforcement Learner (EARL), which combines active pose tracking and reinforcement learning to enable dynamic grasping of moving objects. Unlike static workspace approaches, EARL utilizes a wrist-mounted RGB-D camera for continuous 6-DoF object tracking and grasp planning, demonstrating robustness across multiple robotic arms in complex real-world tasks.

Wang et al. [17] proposed Hand-eye Action Networks (HAN), a novel framework that enables robots to generalize visuomotor skills from demonstrations by approximating human-like hand–eye coordination. Their method integrates 3D visual attention, attention switching, and constrained action targets to mimic how humans dynamically shift visual focus and guide hand movements during sequential tasks. Experiments across grasping, stacking, and tool-use scenarios demonstrated that HAN achieved strong zero-shot generalization to unseen spatial configurations, highlighting the importance of spatial invariance and attention coupling in motor learning. This approach underscores the role of coordinated perception and action in improving adaptability, which is consistent with the findings on cognitive motor training in both robotics and human motor development.

Sailer et al. examined eye movements and hand-eye coordination in a novel task requiring bimanual cursor control. They found three stages in the learning process: first tracking the cursor, then predicting where the cursor would go, and finally focusing directly on the target. This suggests that motor learning involves readjusting eye-hand coordination over time [18].

Zhou and Segawa proposed an EMS-based training system to improve hand- eye coordination in games. Sixteen participants trained playing games with and without EMS. The results showed that EMS improved attention, accuracy, and learning retention more than the traditional method. This suggests that EMS is effective in accelerating motor learning and maintaining hand-eye coordination [19].

2.3. Educational Applications

In addition to perceptual and motor aspects, previous research has also emphasized educational and therapeutic applications of tangram puzzles, demonstrating their value in supporting cognitive development, social interaction, and rehabilitation.

Bernardo et al. [20] explored the therapeutic use of tangram puzzles in children with Autism Spectrum Disorder (ASD) by integrating a humanoid robot (NAO) as a tutor or a peer during the game. The study showed that in Tutor Mode, the robot effectively supported attention and guided children through problem-solving steps, while in Peer Mode, it facilitated turn-taking and cooperative play. Results indicated that the interactive tangram system enhanced engagement, improved social interaction, and supported motor and cognitive development in ASD participants. This work highlights the potential of tangram-based tasks not only for visuospatial and motor skill training but also for fostering social and communicative abilities in therapeutic contexts.

Urwyler et al. [21] conducted a pilot randomized controlled crossover trial examining the effects of dynamic adaptive casual puzzle games delivered via tablet on cognitive function and well-being in healthy middle-aged and older adults. The study included 12 participants, with interventions lasting 8 weeks per phase, unsupervised in home settings. Key findings showed that engagement with puzzle games led to significant improvements in visual attention and visuospatial measures, compared to a control condition (reading newspapers). The authors emphasize that algorithm-based dynamic difficulty adaptation accommodated participants with different skill levels, and that such digital puzzle interventions are feasible and well tolerated in older populations.

Recent research has highlighted the role of game-based interventions in supporting motor and cognitive development. Sabzi [22] demonstrated that structured motor games significantly improved fine motor skills such as response speed, visual-motor control, and upper-limb agility in children with Developmental Coordination Disorder (DCD), suggesting their potential as effective therapeutic tools for rehabilitation. Complementing this perspective, Martinez et al. [23] examined the cognitive implications of both video and board games. Their findings revealed that while overall play time was positively associated with multiple cognitive abilities, video game practice in particular predicted improvements in mental flexibility, visuospatial processing, working memory, and fluid intelligence. In contrast, board game play did not significantly contribute to cognitive performance when controlling for age and education. Together, these studies underscore the diverse ways in which different types of games—ranging from motor-based activities to digital video games—can foster cognitive and motor development.

Recent studies have increasingly emphasized the potential of immersive technologies for enhancing spatial abilities. Piri, Kaplan, and Cagiltay [24] developed Holomental, a Mixed Reality (MR)-based training system designed to improve mental rotation skills. Their mixed-method research compared 2-D computer- based and 3-D immersive testing environments, demonstrating that the MR condition not only reduced cognitive load but also led to significant improvements in participants' mental rotation performance. Furthermore, gesture-based interaction enabled more natural engagement with virtual objects, supporting hand–eye coordination, while three-dimensional representations facilitated depth perception. The study also highlighted the educational potential of Mixed Reality by showing its effectiveness in fostering spatial reasoning, which is essential for STEM-related learning contexts.

3. Problem Statement and Main Content

3.1. Experimental Environment and Setup

The Tangram task was presented through the Unity interface. The experiment was conducted at the TED University Lab. Each participant participated in the experiment on a Magnetic Wildfire auto-stereoscopic display that can transform content into stereoscopic forms without requiring users to wear glasses. The participants were TED University students between the ages of 18 and 25. A total of 19 people participated in the experiment. Care was taken to minimize ambient noise in the laboratory. Furthermore, to prevent glare on the screen in dark mode, no light-emitting devices other than the screen were turned on in the room. To ensure consistent task flow and avoid learning bias, all participants completed six sessions in total—three in the Bright condition and three in the Dark condition. The order of lighting conditions was counterbalanced across participants to minimize order effects. The chosen sample size of 19 participants also aligns with the ITU-R BT.500-15 recommendation, which specifies that at least 15 subjects are sufficient for subjective visual performance assessments.

3.2. Task Description

The Tangram puzzle was chosen for this experiment because it simultaneously exercises visual reasoning and motor control. Solving Tangram tasks requires players to mentally rotate and align geometric shapes, which directly enhances depth perception by transforming 2D pieces into coherent 3D structures. At the same time, physically moving pieces by dragging and rotating them provides a suitable environment for studying motor learning and hand-eye coordination. This combination makes Tangram an ideal experimental tool for investigating the intersection of perceptual and motor processes. Participants recreated the silhouette of a turtle using seven geometric shapes. The pieces must be rotated and positioned to fit the given silhouette exactly. The puzzle begins with the silhouette placed on the right side of the screen and the shapes randomly placed on the left side of the screen. To avoid unnecessary cognitive stress during the task, no explicit time limit was imposed, ensuring that performance reflected natural motor learning rather than time pressure. Similarly, no corrective feedback was provided for incorrect placements in the game. This was intentional to isolate the motor learning process that emerges from repeated interaction with the Tangram puzzle. When all pieces were placed correctly, the system displayed a success message (See in Figure 1).

Figure 1. Final State after successful completion of the Tangram

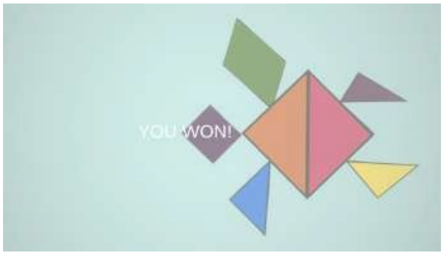

Figure 2. Tangram Mode1 Configuration

Figure 3. Tangram Mode2 Configuration

Figure 4. Tangram Mode3 configuration

- **Bright Condition:** Mode1 → Mode2 → Mode3
- **Dark Condition:** Mode2 → Mode1 → Mode3

To minimize learning effects, three separate game modes were created. These are called Mod1, Mod2, and Mod3 (See in Figure 2, Figure 3 and Figure 4) and differ in the initial positions and orientations of the puzzle pieces. The order of the game modes in the dark and bright options was set differently to prevent pattern memorization.

3.3. Data Collection

The primary performance metric in this study was task completion time, defined as the duration (in seconds) between the moment participants initiated the first interaction with a Tangram piece and the moment the system detected a correct final configuration. This variable reflects both motor efficiency and perceptual processing speed. All timing data were automatically recorded by the Unity engine using an internal timer function, ensuring millisecond-level precision and eliminating human measurement bias. Each trial was logged into the system console immediately upon task completion, including the participant ID, lighting condition (Bright or Dark), and game mode.

The recorded data were subsequently processed to derive individual and group-level averages. These metrics were used to evaluate motor learning efficiency and depth perception under different lighting conditions. The resulting values were analyzed statistically using a paired-samples t -test to compare performance between Bright and Dark conditions, and a two-way ANOVA to examine the effects of game mode and individual differences on task completion time. This approach enabled within-subject comparisons and provided robust validation of the observed performance trends.

3.4. System Implementation

Tangram game (See in Fig. 5 and Fig. 6) was developed with the Unity game engine using the C# scripting language. The application was tested on both macOS and Windows platforms. Unity's 2D physics and event-driven architecture were used for dragging, win condition and object interaction.

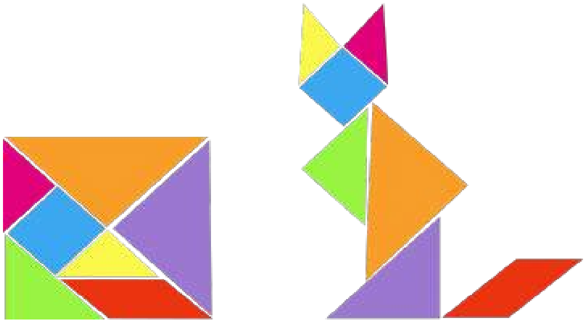

Figure 5. Tangram as an interactive visual puzzle [25]

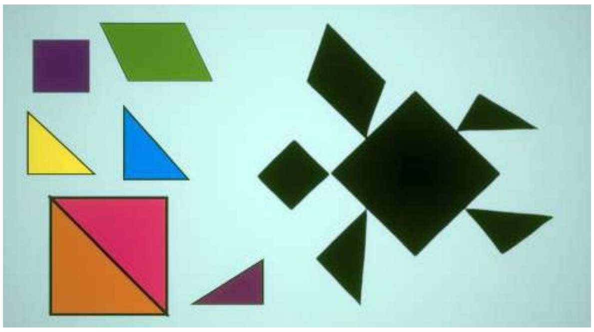

Figure 6. Initial state of the Tangram task showing unplaced pieces and turtle silhouette

Development Overview The game consists of a large number of colored geometric shapes (triangles, squares, and parallelograms). The goal is to drag and rotate these shapes to fit the turtle silhouette.

Drag-and-Drop and Rotation Logic A script coded for players to drag and drop geometric shapes allows users to:

- Click and drag a shape using the mouse
- Rotate the selected shape with mouse scroll wheel

During dragging, only the selected object responds to input, other shapes are unaffected.

Win Condition Logic When a shape is dropped, a function is triggered to verify whether the puzzle is solved. This logic checks if each shape is within the specified tolerance of its target position. An exception is made for the pink and orange triangles, which can be repositioned and still be considered correct.

4. Results and Discussion

As described in the experimental setup, each participant completed the Tangram puzzle in two lighting conditions, both dark and bright, and in three different game modes (i.e., Mode1, Mode2, Mode3). The results representing the task completion times for each user in these lighting conditions and modes are presented in Table 1. As can be observed from these results show that participants generally completed the tasks faster in dark light conditions. Specifically, the average completion time for Mode1 decreased from 72.5 seconds in bright light to 40.1 seconds in dark light. Similarly, the times for Mode2 and Mode3 decreased from 53.7 to 48.5 seconds and from 51.4 to 43.9 seconds, respectively.

User	B-Mode1	B-Mode2	B-Mode3	D-Mode1	D-Mode2	D-Mode3
1	53	34	33	32	35	83
2	58	63	57	58	53	71
3	82	65	78	55	50	46
4	67	46	39	38	42	48
5	85	85	51	52	42	34
6	95	43	47	54	35	32
7	118	61	66	69	53	48
8	51	65	49	43	29	47
9	107	53	39	46	33	31
10	75	51	57	50	44	67
11	77	48	53	60	34	49
12	95	63	48	43	46	32
13	82	68	43	58	29	27
14	40	32	31	31	35	39
15	54	40	52	44	38	36
16	66	34	35	74	45	31
17	62	52	59	37	44	38
18	60	76	91	53	50	45
19	51	39	46	25	25	31
Average	72.53	53.58	51.26	40.11	48.53	43.95

Table 1. Task completion times (in seconds) for each user under bright (B) and dark (D) conditions across three game modes.

Fig. 7 presents the comparison of average completion times for each game mode under bright and dark lighting conditions. The results of the experiment showed that participants improved their performance when they moved from bright to dark conditions. This performance increase supports the hypothesis that repeated interaction with the game supports motor learning over time.

In addition, the average completion time for Mode 1 under bright conditions (72.5 seconds) was higher than for Mode 2 (53.7 seconds) and Mode 3 (51.4 seconds) (See in Fig. 7). This pattern suggests that the initial exposure to the task demanded greater cognitive and attentional resources. Nevertheless, participants demonstrated progressive improvement even within the bright condition, indicating that practice contributed to increased efficiency and adaptation across subsequent trials. The error bars shown in Fig. 7 also reveal smaller variability in the dark condition, suggesting that participants achieved more consistent performance once perceptual adaptation occurred. Overall, the bar plot supports the interpretation that both motor learning and perceptual familiarity contributed to faster and more stable task execution in later modes and darker environments. Participants improved their performance even more when they moved to the dark condition, both because they had become accustomed to the game and because their depth perception was altered by the dark environment. The findings suggest that skills acquired during the initial stage were successfully transferred and applied in subsequent stages, reflecting both motor learning and perceptual adaptation.

The study involved 19 participants who completed tasks under both conditions, represented by Bright and Dark. Since each participant experienced both conditions, a paired-samples t-test was conducted to determine whether there was a significant difference between the two conditions (See in table 2. This within-subject comparison allowed direct assessment of the effect on performance. The analysis revealed a statistically significant difference between Bright Mean ($M = 59.12$, $SD = 12.90$) and Dark Mean ($M = 44.19$, $SD = 8.28$), $t(18) = 5.17$, $p < .001$. Participants performed tasks faster in the Dark Mean condition, suggesting that this condition facilitated quicker task completion. These findings indicate that the experimental conditions can have a substantial effect on task performance and highlight the importance of environmental or contextual factors in cognitive processing.

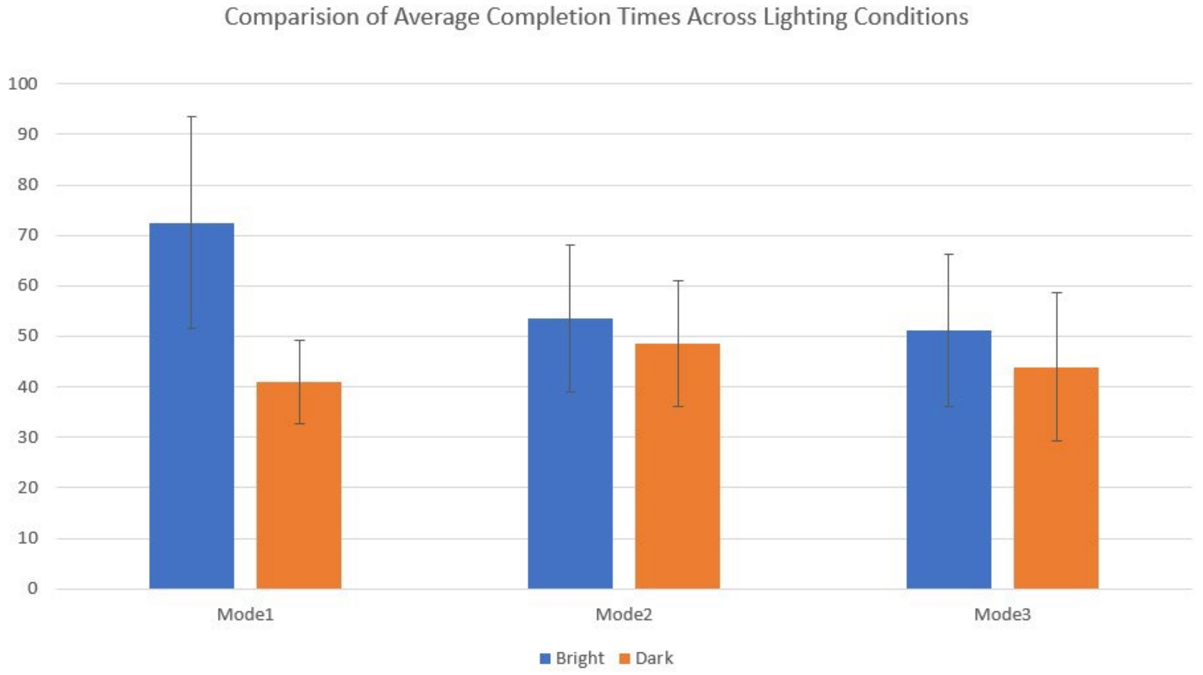

Figure 7. Comparison of average task completion times across game modes under light and dark conditions, with error bars representing standard deviations.

Statistic	Bright Mean	Dark Mean
Mean (M)	59.12	44.19
Variance	166.42	68.58
Observations (n)	19	19
Pearson Correlation	0.359	
Hypothesized Mean Difference	0	
Degrees of Freedom (df)	18	
t Statistic	5.17	
Two-tailed p-value	6.38×10^{-5}	
t Critical (two-tailed)	2.10	

Table 2. Paired-samples t-test statistics for Light Mean and Dark Mean

A two-way analysis of variance (ANOVA) was conducted to investigate the effects of game mode (columns) and individual participant differences (rows) on task completion times under both bright (light) and dark conditions. The analysis was performed separately for each lighting condition to assess whether environmental lighting influenced the variability of performance across different game modes.

For the bright condition (see Table 3), the ANOVA results revealed a significant effect of game mode, $F(2,36) = 13.27$, $p < 0.001$, indicating that task completion times differed meaningfully across the three game modes. Additionally, participant-related differences were also significant, $F(18,36) = 2.56$, $p = 0.008$, suggesting that individual variability contributed to performance outcomes. The error term represents unexplained variance after accounting for these factors.

In the dark condition (see in Table 3), the effect of game mode was not statistically significant, $F(2,36) = 2.60$, $p = 0.088$, although it approached trend-level significance, suggesting a possible minor influence of mode under low-light conditions. Participant differences were not significant in the dark condition, $F(18,36)= 1.58$, $p = 0.118$, indicating that individual variability was less pronounced compared to the bright condition.

Bright Condition						
Source	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	8986.81	18	499.27	2.56	0.00796	1.90
Columns	5171.09	2	2585.54	13.27	0.000048	3.26
Error	7012.25	36	194.78	-	-	-
Total	21170.14	56	-	-	-	-
Dark Condition						
Source	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	3703.54	18	205.75	1.58	0.118	1.90
Columns	675.40	2	337.70	2.60	0.0882	3.26
Error	4675.93	36	129.89	-	-	-
Total	9054.88	56	-	-	-	-

Table 3. Two-way ANOVA results for task completion times under the Bright and Dark conditions.

Overall, these findings suggest that lighting conditions modulate the influence of both task difficulty (game mode) and individual differences on performance. These results highlight the interaction between environmental lighting and task structure in influencing visual-spatial performance, and they underscore the need to consider both task characteristics and individual differences when interpreting cognitive and motor task performance.

5. Conclusion

Reframed through a HCI lens, this study explored how Tangram gameplay mediates motor learning and depth perception in users interacting with complex spatial systems. Results indicated progressive improvements in participants' task performance, attributable to the iterative refinement of motor strategies and greater interface fluency gained through continued interaction, regardless of variations in environmental lighting. Notably, transitions from bright to dark conditions revealed that changes in perceptual cues, as manipulated by the interface context, could positively affect users' depth perception and task efficiency. By systematically varying environmental parameters during Tangram play, the study provided a nuanced assessment of how interface conditions and embodied interaction jointly shape the processes of motor learning and spatial per caption offering actionable insights for the design of adaptive, skill-enhancing interactive systems.

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