Own-Experience Learning in a Digital Playground: Measuring Children's Causal Reasoning Using Video Games

Joshua Juvrud, Dana Glackin, Zoe Kross and Carolyn Stewart

June 10, 2024

Own-experience learning in a digital playground: Measuring children's causal reasoning using video games

ABSTRACT

The evolution of playgrounds into digital spaces within video games reflects a significant shift in how we can understand the importance of learning through play. However, specific mechanics of learning opportunities in video games, including visual exploration and manipulative investigation, have yet to be fully explored in relation to particular learning outcomes in children. This study examined causal reasoning through own-experience digital play in 4-5 year old children (*N*=37), and whether time constraints would impact learning. Results showed that children learned causal reasoning through exploration and own-experience in digital play. However, children were unable to transfer learned causal properties to a novel scenario. Moreover, time constraints had no impact on the children's ability to learn causal properties. Implications from these findings suggest that video games present a valuable and efficient digital playground for explorative learning.

Keywords

explorative play, self-experience learning, causal reasoning, children, video games

INTRODUCTION

Children, as they engage in play, simulate aspects of their experiences to explore objects in their environment. In the context of play, visual exploration and manipulative investigation hold significant importance for learning (Fesnson et al. 1985; Sarid et al. 1997); that is, changing and adapting behavior based on experiences and knowledge. Visual exploration allows children to observe and understand their surroundings by looking at people and objects. Children gather a substantial amount of information about the world primarily through visually exploring their environment. Studies on the developing patterns of visual attention have proven especially insightful in revealing how children's abilities to process and remember information change as they grow older, such as through demonstrative learning (Sobel et al. 2014; Syamsuardi et al. 2023) and social learning (Wood et al. 2013). This visual exploration serves as a fundamental means for children to grasp the features of their environment. Simultaneously, manipulative investigation involves hands-on exploration and interaction with objects. Through physically engaging with their surroundings, children gain a deeper understanding of the properties and characteristics of different elements in their environment (citation).

Over the course of child development, as play continues to evolve (such as the onset of pretend play) and environments for play expand (physical playgrounds and digital

Proceedings of DiGRA 2024

playgrounds, or video games) visual exploration and manipulative investigation continue to be fundamental for both engaging in play and learning through play (Fesnson et al. 1985). These two types of inquiry—visual exploration and manipulative investigation —continuously contribute to shaping children's evolving perceptions of their world. Researchers have often analyzed each type in isolation to understand their respective contributions in play (Knox 1997). However, it's crucial to remember that these behaviors are typically interconnected in a playing child, especially in the context of playgrounds. There is limited research in examining these factors jointly, and very few studies that have measured these in the context of video games. The current study examined to what extent visual exploration and manipulative investigations are used in explorative play in a video game to learn specific causal properties of objects.

Digital playgrounds

Playgrounds have been shown to serve as dynamic spaces that promote own-experience learning in children through various interactive and sensory activities. Physical exploration, risk-taking, and problem-solving opportunities on playground equipment encourage hands-on learning. Trial and error learning, body awareness, and coordination are fostered as children navigate the unstructured environment of the playground. It has been argued that similar affordances for learning exist in digital playgrounds.

Traditional physical playgrounds have transformed into digital playgrounds as a result of advancements in technology and the increasing prevalence of video gaming. In Sweden, it is estimated more than 87% of school-age children play video games (Swedish Media Council 2018). The evolution of playgrounds into digital spaces within video games reflects a significant shift in recreational and educational activities, as well as a shift in how we can understand the importance of learning through digital play.

Previous studies have explored the impact of video games on social interaction, cognitive development, and overall well-being in children (Hallbrook et al 2019; Smirni et al 2021). Digital playgrounds in video games provide a virtual space for players to engage in various activities, socialize with others, explore imaginative worlds, and present new opportunities for learning through play. These virtual environments often replicate the elements of traditional playgrounds, such as exploration, own-experience, and playfulness. But the specific mechanics of these learning opportunities in video games, including visual exploration and manipulative investigation, have yet to be explored in relation to particular learning outcomes. It remains unclear to what extent the digital playgrounds found in video games have the potential to effectively integrate visual exploration and manipulative investigation to contribute to specific types of learning in children.

Causal learning

One type of crucial learning in early development is causal reasoning. Learning causal reasoning in childhood holds immense importance as it forms the foundation for a child's cognitive development and problem-solving skills. Causal reasoning involves understanding cause-and-effect relationships, comprehending the consequences of actions, and making connections between objects and events. From a very young age, children are extraordinary causal learners. Infants can recognize certain aspects of physical causality and toddlers can understand causal relations concerning other individuals' emotions (Sobel et al. 2014). By the time children are in preschool, they begin understanding that certain events can expose hidden causal relations (Sobel et al. 2014). As children explore the world around them, they have the ability to make accurate causal inferences from their surroundings and integrate new information with their previously held beliefs (Engle et al. 2021; Walker et al. 2016).

It has been demonstrated in classic developmental psychology paradigms that through demonstration and observational learning, children can efficiently learn the causal power of a novel object, or the influence that it has on another novel object (Gopnik et al. 2000). Children are known to have causal reasoning abilities such as making predictions about the future and reasoning about counterfactuals (Sobel et al. 2009). However, it is not clear at what to what extent children can discover causal powers without the help of others (Gopnik et al. 2000) or in digital environments.

Two of the main ways children come to understand the causal powers of objects is through observational and own-experience learning (Thompson et al. 2004; Hartman et al. 1999). In observational learning, children learn by watching another person perform an action first (Thompson et al. 2004). In own-experience learning, children obtain skills and information through their own actions (Hartmann et al. 1999). Previous research performed by Gopnik et al. (2000) used a "blicket detector" to understand at what age children can learn the causal powers of objects. Placing objects labeled as "blickets" on the detector caused the machine to light up and play music, but placing objects that were not "blickets" on the detector had no effect on the machine. In this body of previous work, at the start of each experiment, the researchers showed the participants which objects were "blickets" and which objects were not through demonstration. The children then had to choose the object that they believed caused the machine to turn on. The demonstration that the researchers gave the children at the start of the study resulted in the children learning through observational, and as result, prevented the children from using exploratory learning to discover the causal powers of the object.

To what extent can children learn causal reasoning through own-experience play? Previous research has shown that children who discover information on their own are more likely to remember it, and they treat information generated from their own actions as important for causal learning (Sobel et al. 2010). Their actions provide acquisition of information not present in observations of the environment. Additionally, when learners make decisions through their own exploration, they are able to focus on the particular interventions and outcomes that are important for learning causal structure and decision making (Sobel et al. 2006). Therefore, when the researchers in the previous blicket study gave the children information about which objects caused the machine to turn off, they did not allow for the children to have the opportunity to learn from their own experiences.

Current study

The current study investigated to what extend self-experience play in a video game can result in learning causal reasoning of objects. To examine this, the basic blicket study paradigm was replicated in a video game, but without providing participants demonstrations or instructions. Children were given a video game that had no instructions for the novel objects and tasks and were allowed to play in the digital environment at their own pace and own initiative. Children were therefore allowed the opportunity to use exploration and own-experience to learn the causal powers of the objects in the game.

In a separate condition, time constraints were added during their play to constrain exploration. Time constraints are present in many aspects of children's lives, especially in schools and classrooms (McDonald, 2001). When children are faced with time constraints, it is likely that they will experience stress from that time constraint (Hirt et al., 2020). Thus, when a stressor of this nature is integrated into a child's learning (or play), there is a chance that learning could be negatively impacted (Onwuegbuzie et al. 1995; Quas 2014). For example, stress has been shown to negatively affect memory, and when a child is stressed while learning, they may experience deficits in short term memory and recollection of events that they just learned. Previous literature suggests that placing time constraints on an individual is likely to act as a stressor (Caviola et al. 2017). Time constraints have been repeatedly shown to cause stress in individuals, which usually leads to less exploration, poorer judgment, a decrease in cognitive skills, and an increase in physical stress symptoms (Caviola et al. 2017; Gonzalez 2004; Roberts et al. 2019). As a result, the current study used time constraints to examine if exploration and self-experience learning during play is impacted by associated effects of time stress and compare these findings with unconstrained free-play.

The results of this study have significant implications for our understanding of children's learning during explorative, self-experience play in video games. If children show successful learning of causal reasoning, similar to traditional lab-based paradigms used by Gopnik et al. (2000), then it could be suggested that video games provide a potentially useful platform for learning without the constraints of adult demonstration. This would have significant implications for educators, game designers, health professionals, and others who are invested in providing rich learning opportunities for children using digital media, such as video games. Provided that the majority of children already engage daily with digital playgrounds, it is important to understand what game mechanics and psychological processes are at play, during children's own digital play.

METHOD

Participants

Participants (N = 37; male = 19) in the study included 4-5-year-old children (M = 4.72 years, SD = .31) from the greater [anonymized for review] area. The age group was chosen based on the performance of children between the ages of 4- and 6-years in the original blicket study, which indicated that the majority of children at 4-5 years could demonstrate causal learning (Gopnik et al. 2000). Research assistants called parents of children who had previously volunteered to participate in infant and child studies. Parents of children received compensation for participating in the form of a 10€ gift voucher and provided informed consent. The study was conducted in accordance with the standards specified in the 1964 Declaration of Helsinki and approved by the local ethics committee [anonymized for review].

Materials

Ludum Platform

The purpose of the *Ludum* Platform was to assess the participants' ability to learn the causal properties of the objects. The *Ludum* Platform is a commercial-quality game software developed in collaboration with the department of game design and the department of psychology at [anonymized for review] This platform allows for control and manipulation of game design elements, as well as detailed data analysis of particular player behaviors (for more information, see the Ludum Platform wiki: https://gitlab.speldesign.uu.se/ludum/LudumDetector/-/wikis/home). Therefore, the *Ludum* Platform is a useful tool to study questions relevant to game design and player behavior. Researchers were able to edit the shape and color of the objects, where the objects were placed in the room, and the values of the objects.

The *Ludum* Platform (Figure 1a) is a first-person game that takes place in a large space of interconnected rooms that may contain objects (Figure 1c), a detector, and a button. To solve tasks in each room, comparative criteria of object value and detector value must be met. When these criteria are met, the door would open and allow progression to the next room or the completion of the game. For example, a series of objects could have the following values: object A = 1, object B = 0, object C = 0. In this example, the detector could be given a value of <1, meaning that both object B and object C would be correct solutions, as would both objects B and C simultaneously. However, if the detector was set to a value of =1, then only object A would be correct. When the button was pressed, the camera became locked to display the detector and the objects placed on the detector, and the resulting action of the door (see Figure 1b). This was to standardize the visual information provided to each child after pressing the red button.

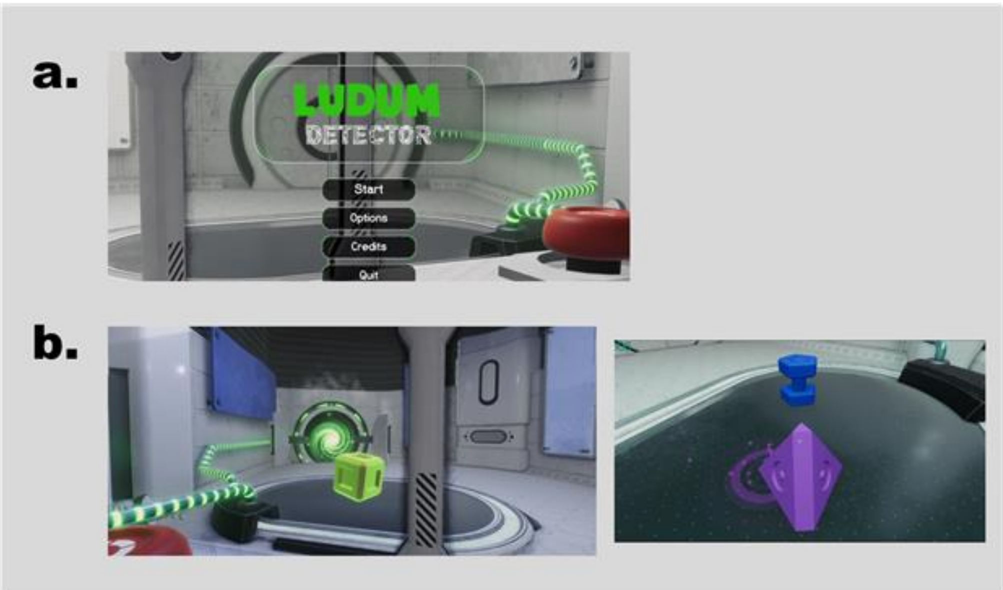

Figure 1. (a) The title screen of the *Ludum* Platform, and (b) screenshots of the rooms with the objects, detector, and red button.

There were multiple objects in each room, and objects were assigned an invisible value that remained the same in every room. The object's shape and color were pseudo-randomized across participants. Participants used a joystick to maneuver around the room. When the participants faced the object and were close enough to pick it up, the object would be highlighted by a white glow. The objects could be picked up, put down, moved around the virtual room, and placed on the detector. When the objects were on the detector, a button could be pressed to input the selection and check the value of the object(s). The door would glow green with an audible chime noise to indicate the 'blicket', or causal object, was correctly placed on the detector.

Questionnaires

Questionnaires included a children's screen use questionnaire and parental attitudes toward screen use questionnaire. Both questionnaires were completed by the parents at the lab prior to testing.

The children's screen use questionnaire (adapted from Juvrud et al. 2021) contained 9 items and consisted of three subscales: children's stress, children's screen use, and parental attitudes towards screen use. The first section of the questionnaire measured how frequently the children watched television or used laptops, game consoles, and mobile phones/tablets on weekdays and on weekend days. One example of a question is "On a normal weekday, select the time that your child spends using the following devices: television, laptop/computer, mobile phone/tablet, game consoles." The options presented were: "None, 1-59 minutes, 1-2 hours, 2-3 hours, 3-4 hours, 4 or more hours."

The parental attitudes towards screen use questionnaire contained 9 items and measured how parents felt about young children (0-5) using digital media and the impact that digital media has on children. One example of a question is, "The use of a computer can promote long-term physical, emotional or intellectual developmental damage." The options presented were strongly agree, agree, neither agree nor disagree, disagree, and strongly agree."

Composite scores were calculated for each questionnaire and subscales and entered into the final analysis.

Procedure

Upon entry into the lab room, the child's parent signed the consent form and completed the questionnaires. The researcher instructed the parents not to interact with the child or help the child in any way, The child sat in front of the computer, with the parent seated in the back of the room out of sight of the child, and the study began when the child indicated they were ready to play the computer game.

The layout and progression of each room is presented in Figure 2. The purpose of the first room was to familiarize the participant with the controls of the game. The researcher instructed the child in using the joystick to move, pushing the button to pick up or put down objects, and interacting with the red button. Upon pushing the red button, the door opened and the child walked through it. There was a single object in the room, and the door was already open. When the child expressed they had an understanding of the controls, they were instructed to walk through the open door.

After the practice room, no instructions were provided to the child by the researcher or parent.

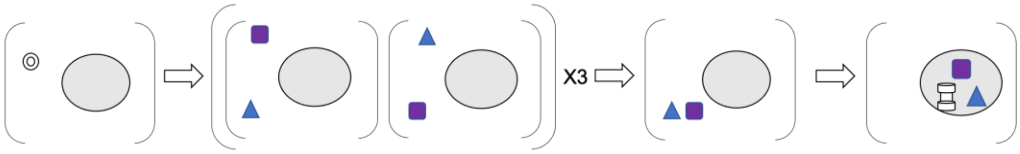

Figure 2. Configurations of the rooms that the participants entered. The room order is presented from left to right, with the left most room being the first practice room, and the right most rooms being the test rooms. The second and third rooms were the learning rooms. They were alternately repeated three times.

Upon entering the second room, children were shown on-screen text that read “Try to open the door!”. The purpose of the second room was for the child to learn that placing an object (for the sake of describing the procedure, we will call this object the “blue triangle”) on the detector and pushing the red button opened the door. When another object except the blue triangle was on the detector and the child pushed the red button, the door did not open. The blue triangle was always placed closest to the child, and the other object was at the other end of the room. After the completion of the second room, they were automatically transported into the next room when they walked through the door.

The purpose of the third room was for the child to learn that placing the blue triangle on the detector opened the door, despite it not being the most efficient option. Placed in the third room was another object closest to the child, and the blue triangle at the other end of the room (opposite configuration of the second room). After successfully opening the door by placing the blue triangle on the detector and pressing the red button, the child was automatically transported to the next room once they walked through the door.

Rooms four and six were the same as room two, and rooms five and seven were the same as room three. The purpose of repeating these rooms was to give the child multiple opportunities to learn that the blue triangle opens the door. Altogether, each child participated in a total of six learning trials, three of each of the efficient and non-efficient placement rooms.

The purpose of the eighth room was to test if the child had learned that the door opened when the blue triangle was on the detector. Placed in the eighth room was a blue triangle and another object next to each other, close to the child but equal distance from each other and from the player. After placing the blue triangle on the detector and opening the door, the child was automatically transported to the next room once they walked through the door.

Finally, placed in the ninth room was a blue triangle, another object, and a novel, previously unseen object. All three objects we placed already on the detector, requiring the child to remove objects from the detector, rather than place them on the detector. The purpose of the ninth room was to see if the child could apply previously learned causal reasoning to perform a subtractive transformation, instead of additive.

Upon completion of the ninth room, the child was shown on-screen text that said "You won!". After this screen, the child went to another room where they could make objects fall from the sky and stack into a pile as a reward. Pilot testing indicated that children found this activity to be fun and rewarding.

Participants that were in the time constraint condition followed the identical procedure, but were told at the start of each room that they had two minutes to open the door. In addition to written instructions, the researcher verbally told the child that they had two minutes to open the door. Since children do not yet have a suffcient concept of time, children were told that they had a time constraint without the game actually enacting a consequence when the time was up (Güneş et al. 2020; Womack 2002). In this way, the game simulated the stress of a time constraint without mitigating the child's exposure and ability to learn the causal powers of the objects, compared to the non-timed condition (i.e., the children had equal opportunity to explore and gather self-experience in each room without being cut-off).

Data analysis

Children's performance while playing the game was recorded by the *Ludum* software: number of attempts, number of object moves, and number of looks at objects. Attempts were recorded each time the participant pushed the red button to detect the value of the object(s) that was on the detector, whether a success or failure. A move was recorded whenever the participant picked up and put down any object in the room. A look was recorded each time the participant looked at any object in the room, designated by the object being detectable within the field of vision of the player. The number of attempts and moves of an object were indicative of manipulative investigation, while the number of looks was indicative of visual exploration.

In order to observe children's causal learning, we compared the number of attempts in different rooms in the control condition and the number of attempts in different rooms in the time constraint condition. We selected four rooms as test rooms to examine causal learning: rooms 2, 7, 8 and 9. In room 2, the child was presented with the blue triangle and purple cube for the first time. This was their baseline room and their first attempt at opening the door. Room 7 was the last learning room, where the child had the most experience in testing whether the blue triangle or other object opened the door. The first test room was room 8, where the child was once again presented with objects. This room tested whether the child could identify which block opened the door when both shapes are equally efficient options. Room 9 was the final room in which the child was presented with blue triangle, a previously seen object, and a novel object, each already placed on the detector. This room was designed to test whether the child could transfer the knowledge they had previously learned to a room with a novel object and layout. It was decided to compare certain rooms in each condition in order to observe the effects of practice and learning on children's performance.

We chose to compare control room 2 to control room 7 and time constraint room 2 to time constraint room 7 to look at the effects of practice on causal learning, and whether the participant would choose the blue triangle even when it was the less efficient option. In room 2, the blue triangle was the efficient option since it was closer to the participant, but in room 7 the blue triangle was the less efficient option since it was across the room. If there was a significant difference in number of attempts between rooms 2 and 7 this would suggest that the participant had learned that the blue triangle opened the door and was not just trying to open the door efficiently.

Control room 7 was compared to control room 8 and time constraint room 7 was compared to time constraint room 8. This tested the child's ability to open the door when there is no longer an efficient option. We hypothesized that there should not be a significant difference in attempts between room 7 and 8 since the child would have learned that the blue triangle alone opens the door by the completion of room 7. Therefore, when the objects were side by side in room 8, the child would choose the blue traingle since they have learned that efficiency does not influence which block opens the door.

Unconstrained room 8 was compared to unconstrained room 9 and time constrained room 8 was compared to time constrained room 9. Comparison of these rooms looked at the child's ability to transfer their knowledge that the blue triangle opened the door when they were presented with a room that had a different configuration. We hypothesized that there would not be a significant difference in attempts between room 8 and 9 since the child would have casually learned that the blue triangle is the only object that opens the door to the next room.

The unconstrained group room 9 was compared to time constrained room 9 to see whether the time constraint had an effect on the participants ability to open the door even with a novel object introduced and a different room configuration. We examined room 9 because we predicted that a time constraint may have an impact on causal learning.

Average number of looks across all learning rooms (rooms 2-7) were compared between the unconstrained group and time constrained group. These were compared to see the impact that the time constraint had on how a child explores and subsequently learns across rooms. We hypothesized that there would be a difference in looks between the unconstrained and time constrained group since we predicted that the time constraint would play a significant role in the child's learning strategy and exploratory behavior throughout these rooms.

Average number of looks across both testing rooms (rooms 8 and 9) were compared between the unconstrained and time constrained group. Once the children had the ability to learn which object opened the door, it was important to see how the time constraint affected their performance in the testing rooms. We predicted that there would be a significant difference between the groups because the time constraint could hinder the child's performance in each testing room, and could impact their exploratory behavior.

RESULTS

Manipulative investigations and performance

For means and standard deviations across rooms, see Table 1 and Table 2. Paired sample t-tests were conducted to compare attempts in unconstrained group room 2 and attempts in unconstrained group room 7, and attempts in time constrained room 2 and time constrained room 7. Scores for unconstrained group room 2 were significantly greater than scores for unconstrained group room 7, $t(21) = 3.59$, $p = .002$, $d = 1.84$. Scores for time constrained group room 2 were significantly greater than scores for time constrained group room 7, t(10) = 3.75 , p = .004, d = 1.21. These results suggest that in both the unconstrained and time constrained groups, children had significantly fewer attempts in room 7 than in room 2 because they learned that the causal property of the object that opened the door. Results for attempts by condition are illustrated in Figure 3, moves in Figure 4, and looks in Figure 5.

	Room							
	2	3	4	5	6	7	8	9
Control	2.77(1.77)	2.23(2.18)	1.59(1.22)	1.36(0.79)	1.10(0.29)	1.36(0.79)	1.14(0.35)	4.05(2.58)
Time	3.07(1.49)	2.38(1.33)	1.92(1.78)	1.15(0.38)	1.17(0.58)	1(0)	1(0)	4.5(3.26)

Table 1. The mean number of attempts and standard deviation for each room. The mean number of attempts is the first number, followed by the standard deviation in parenthesis.

	Room							
	2	3	4	5	6	7	8	9
Control	23.36(16.06)	14.05(17.94)	7.09(6.54)	7.05(4.12)	5.86(6.78)	7.55(4.62)	6.09(4.37)	34.45(22.71)
Time	24.86(25.25)	16.85(10.35)	9.17(7.74)	9.08(6.13)	4.67(3.50)	6.17(3.21)	9.15(5.87)	30.83(14.77)

Table 2. The mean number of looks and standard deviation for each room. The mean number of looks is the first number, followed by the standard deviation in parenthesis.

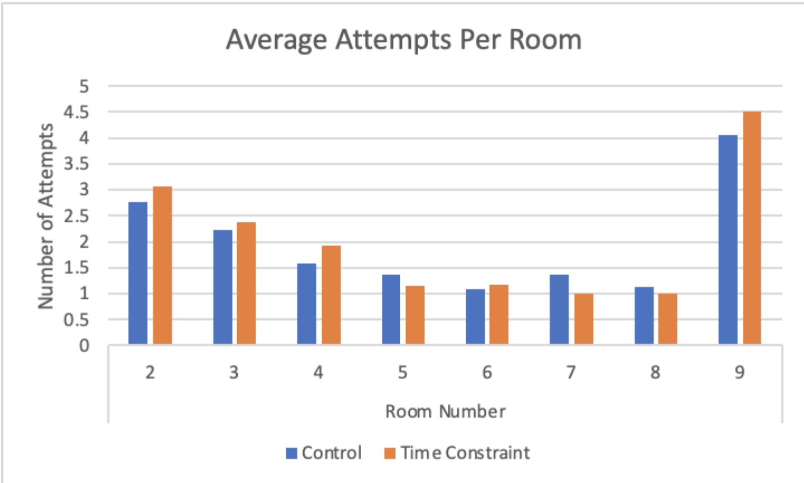

Figure 3. Mean number of attempts per room for each condition.

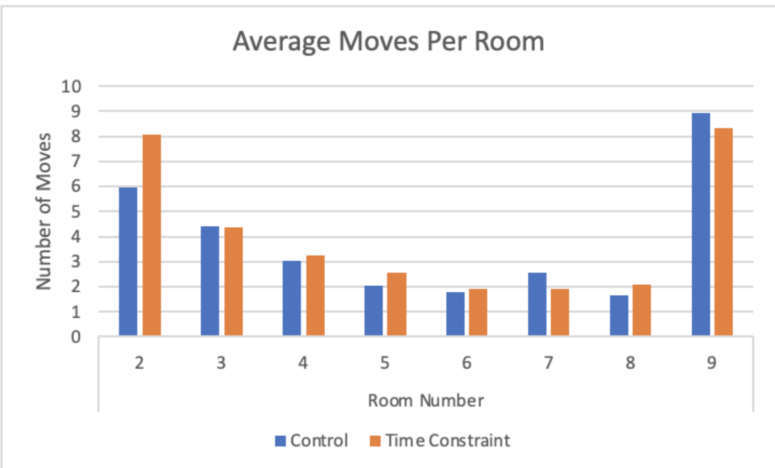

Figure 4. The mean number of moves per room in each condition.

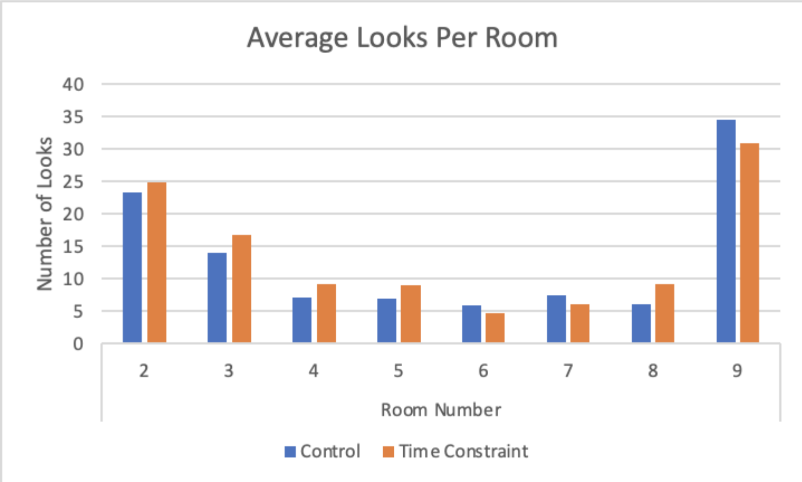

Figure 5. The mean number of looks per room for each condition.

Performance and efficiency

Paired samples t-tests were conducted to compare attempts in unconstrained group room 7 and 8, and in time constrained room 7 and time constrained room 8. Scores for unconstrained group room 7 were not significantly greater than scores for unconstrained group room 8, t (21) = 1.31, p = .204, d = .81. Scores for time constrained room 7 were not significantly greater than scores for time constrained room 8, t (11) = 1.00, p = .339, d = .58. These results suggest that by room 7 the child had learned the causal property of the object that opened the door, and that they are able to transfer that knowledge to room 8.

Visual exploration

There was not a significant difference in the scores for average looks in room 2-7 for the unconstrained condition and average looks in room 2-7 time unconstrained condition, t(10) = .233, p = .821. These results suggest that exploratory behavior in learning was not impacted by a time constraint.

An independent sample t-test was conducted to compare average number of looks in rooms 8-9 for the unconstrained condition and average number of looks in room 8-9 for the time constraint condition. There was not a significant difference in the scores for average looks in room 8-9 unconstrained condition and average looks in room 8-9 time constrained condition, t(2) = .016, p = .989. These results suggest that exploratory behavior in performance was not impacted by a time constraint condition.

There was no correlation between performance on the *Ludum* game and the results from the digital experience questionnaire or the parental attitudes toward digital media questionnaire. There was no difference in the questionnaires between the unconstrained and time constraint conditions.

Transfer of knowledge

Paired samples t-tests were conducted to compare attempts in the unconstrained condition room 8 and attempts in unconstrained group room 9, and attempts in time constrained room 8 and time constrained room 9. Scores for the unconstrained condition room 8 were significantly greater than scores for unconstrained group room 9, t (19) = 5.10, p = .000, d = 2.58. Scores for time constrained group room 8 were significantly greater than scores for time constrained group room 9, t(11) = 3.72, p = .003, d = 3.26. These results suggest that in both the unconstrained and time constrained conditions, participants were able to transfer their learning to room 8, but were unable to transfer what they had learned to the room configuration in room 9.

Time constraint

To examine if the time constraint had an effect on children's causal learning, an independent sample t-test was conducted to compare attempts in the unconstrained group room 9 and attempts in time constraint group room 9. There was not a significant difference in the scores between the conditions in room 9, t(30) = .432, p = .669, d = 2.85. These results suggest that there was no difference in performance when a time constraint was added.

DISCUSSION

The current study aimed to discover if children could learn to infer an object's causal properties through own-experience play, without being given a demonstration, and whether a time constraint would impact their learning. The results support our prediction that children were able to learn the causal properties of an object without first being shown the causal properties that the object had, demonstrating efficient own-experience learning. However, children were unable to transfer their knowledge about causal properties when the object was presented to them in a different scenario than the one in which they previously learned, and when an additional novel object was presented. Moreover, a time constraint had no impact on the children's ability to learn the causal powers of an object.

Participants learned the causal properties of the objects they were presented with in every room, without any demonstration and through their own actions. Results showed that both visual exploration and manipulative investigation were used in play, and the rate of visual exploration and manipulative exploration both decreased as performance became more efficient. We can infer learning, as opposed to efficiency of actions, because even when the object with causal properties was not the efficient option to place on the detector, or when there was no efficient option at all, the majority of children still chose to put the object they had learned to have causal properties on the detector.

These results confirm Gopnik et al.'s (2000) findings that children are able to learn the causal powers of objects. However, unlike the original studies that relied on demonstration, the results support the theory that given the opportunity to discover information about causal powers on their own, children are able to learn the causal properties of an object. It was previously unclear at what age children learn causally through their own-experience in such a paradigm, or if such learning can occur in a video game task. These findings suggest that 4-5 year old children are able to learn the causal power of objects through own-experience play in a video game task.

Even though the children learned the causal power of an object to open a door, they were unable to apply this knowledge when presented with a room that had a novel scenario and a novel object. In the final tests room, which contained a previously unseern object and when the objects were placed in a new configuration that required a different transformative solution (subtraction instead of addition), children took significantly more attempts to open the door, moved the objects significantly more times, and had significantly more visual exploration of the objects. The addition of two novel factors could have caused the children to become overwhelmed and hesitant to use their previous knowledge, instead defaulting back to general explorative behavior. It is also possible that in the new scenario, children at this age are unable to transfer their previously learned knowledge to a novel transformative solution. Since the positions of the objects also changed, already placed on the detector, requiring the objects to be removed instead of added, it is therefore possible that this change in problem solving was sufficiently challenging enough to inhibit previously learned causal properties, and children were unable to transfer prior knowledge and transform the solution to the novel problem. An alternative, low-level perceptual explanation, could be that the new object in the room may have been sufficiently novel and therefore attention grabbing to the children, sparking exploration about what would happen if it was on the detector. In this case, they may have chosen to test the novel object to see what happened even if they already knew the causal properties of the familiar objects. However, the children in the timed condition also engaged in exploration of the novel object and their visual exploration and manipulative investigations also increased, making this explanation unlikely.

Results from the current study demonstrate that when given the opportunity to engage in own-experience learning through explorative play, visual attention and manipulative investigations significantly contribute important input to children's ever-changing conceptions of their world. By examining a specific aspect of learning, casual reasoning, we can see that video games provide a rich opportunity for such explorative play, similar to what is found in real-world play and in classic developmental psychology paradigms that examine learning. This opens the door to further investigations and replications of traditionally more constrained tasks examined in a laboratory setting, which often rely on precise instructions and demonstrations. It also suggests potential for educators, game designers, parents, and others interested in using digital tools for learning. Future studies should also examine to what extent children are able to transfer the knowledge that they learn in a video game to a real-life situations. For example, once the children have completed the *Ludum* video game, children could be presented with a physical blicket detector and the same objects that were in the video game in block form and examine if the causal reasoning learned in the video game transfer to the physical objects.

Conclusions

The main findings of this study suggest that 4-5 year old children are able to learn the causal properties of objects through their own visual exploration and manipulative investigations, without the need for demonstrations or instructions. However, their knowledge about the causal powers of objects may not be solidified and they struggle to apply their knowledge to novel situations. These findings tell us that children are able to understand objects in their environment through exploration and own-experience in digital play. Allowing children opportunities to explore and engage in own-experience play is essential to a quality learning experience and longer-lasting knowledge (Yuniarto et al. 2020). Educators are faced with the challenge of optimizing the learning of children today, but the research emphasizes the need for exploratory behavior for children to learn about their world. Video games appear to present a valuable and efficient digital playground for such explorative learning.

ACKNOWLEDGMENTS

[anonymized for review]

REFERENCES

Caviola, S., Carey, E., Mammarella, I. C., & Szucs, D. (2017). Stress, Time Pressure, Strategy Selection and Math Anxiety in Mathematics: A Review of the Literature. Frontiers in psychology, 8, 1488. https://doi.org/10.3389/fpsyg.2017.01488

Engle, J., & Walker, C. M. (2021). Thinking Counterfactually Supports Children’s Evidence Evaluation in Causal Learning. Child Development. https://doi.org/10.1111/cdev.13518

Fenson, L., & Schell, R. E. (1985). The origins of exploratory play. Early Child Development and Care, 19(1-2), 3-24.

Gonzalez, C. (2004). Learning to Make Decisions in Dynamic Environments: Effects of Time Constraints and Cognitive Abilities. Human Factors: The Journal of the Human Factors and Ergonomics Society, 46(3), 449–460. https://doi.org/10.1518/hfes.46.3.449.50395

Gopnik, A., & Sobel, D. M. (2000). Detecting Blickets: How Young Children Use Information about Novel Causal Powers in Categorization and Induction. Child Development, 71(5), 1205–1222. https://doi.org/10.1111/1467-8624.00224

Güneş, G., & Şahin, V. (2020). Preschoolers’ thoughts on the concept of time. The Journal of Genetic Psychology: Research and Theory on Human Development, 181(4), 293–317. https://doi-org.ezproxy.middlebury.edu/10.1080/00221325.2020.1753645

Halbrook, Y. J., O’Donnell, A. T., & Msetfi, R. M. (2019). When and how video games can be good: A review of the positive effects of video games on well-being. Perspectives on Psychological Science, 14(6), 1096-1104.

Hirt, C., Eckard, M., & Kunz, A. (2020). Stress generation and non-intrusive measurement in virtual environments using eye tracking. Journal of Ambient Intelligence and Humanized Computing, 11(12), 5977–5989. https://doi.org/10.1007/s12652-020-01845-y

Juvrud, J., Ansgariusson, G., Selleby, P., & Johansson, M. (2021). Game or watch: The effect of interactivity on arousal and engagement in video game media. IEEE Transactions on Games, 14(2), 308-317.

Knox, S. H. (1997). Play and play styles of preschool children. University of Southern California.

McDonald, A. S. (2001). The Prevalence and Effects of Test Anxiety in School Children. Educational Psychology, 21(1), 89–101. https://doi.org/10.1080/01443410020019867

Onwuegbuzie, A. J., & Seaman, M. A. (1995). The Effect of Time Constraints and Statistics Test Anxiety on Test Performance in a Statistics Course. The Journal of Experimental Education, 63(2), 115–124. https://doi.org/10.1080/00220973.1995.9943816

Quas et al. (2014). Effects of stress on memory in children and adolescents: Testing causal connections. https://www.tandfonline.com/doi/full/10.1080/09658211.2013.809766.

Roberts, S. O., & Horii, R. I. (2019). Thinking Fast and Slow: Children's Descriptive-To-Prescriptive Tendency Under Varying Time Constraints. Journal of Cognition and Development, 20(5), 790–799. https://doi.org/10.1080/15248372.2019.1599001

Sarid, M., & Breznitz, Z. (1997). Developmental aspects of sustained attention among 2-to 6-year-old children. International Journal of Behavioral Development, 21(2), 303-312.

Smirni, D., Garufo, E., Di Falco, L., & Lavanco, G. (2021). The playing brain. the impact of video games on cognition and behavior in pediatric age at the time of lockdown: a systematic review. Pediatric reports, 13(3), 401-415.

Sobel, D. M., & Legare, C. H. (2014). Causal learning in children. Wiley Interdisciplinary Reviews: Cognitive Science, 5(4), 413–427. https://doi.org/10.1002/wcs.1291

Sobel, D. M., & Sommerville, J. A. (2009). Rationales in children's causal learning from others' actions. Cognitive Development, 24(1), 70–79. https://doi.org/10.1016/j.cogdev.2008.08.003

Sobel, D. M., & Sommerville, J. A. (2010). The Importance of Discovery in Children's Causal Learning from Interventions. Frontiers in Psychology, 1. https://doi.org/10.3389/fpsyg.2010.00176

Sobel, D. M., & Kushnir, T. (2006). The importance of decision making in causal learning from interventions. Memory & Cognition, 34(2), 411–419. https://doi.org/10.3758/bf03193418

Syamsuardi, S., Syawaluddin, A., & Sahade, S. (2023). The Effect of Demonstration Methods to Improve Science Thinking Skills In Children Aged 5-6 Years. Journal of Educational Science and Technology, 9(1), 77-85.

Thompson, D. E., & Russell, J. (2004). The Ghost Condition: Imitation Versus Emulation in Young Children's Observational Learning. Developmental Psychology, 40(5), 882–889. https://doi.org/10.1037/0012-1649.40.5.882

Walker, C. M., Lombrozo, T., Williams, J. J., Rafferty, A. N., & Gopnik, A. (2016). Explaining Constraints Causal Learning in Childhood. Child Development, 88(1), 229–246. https://doi.org/10.1111/cdev.12590

Womack, S. 2002. Young children cannot tell time on old clocks. The Daily Telegraph: London.

Wood, L. A., Kendal, R. L., & Flynn, E. G. (2013). Whom do children copy? Model-based biases in social learning. Developmental Review, 33(4), 341-356.

Wyeth, P. (2008). How young children learn to program with sensor, action, and logic blocks. The Journal of the learning sciences, 17(4), 517-550.

Yuniarto, L. S., Gerson, S. A., & Seed, A. M. (2020). Better all by myself: Gaining personal experience, not watching others, improves 3-year-olds' performance in a causal trap task. Journal of experimental child psychology, 194, 104792.